Niger GLOBE Program

Atmosphere Program

Study Site Set-up Check List

Setting up your Atmosphere Study Site can seem confusing with all of the different procedures to follow. In that light, here is a quick list of what needs to be done along with the necessary protocols for each step.

Task	*Protocols*
1. Select several options for the study site at the school	Study Site Set-up -1
2. Using a tape measure and a clinometer select the best study site at your school	Study Site Set-up -1
3. Document your Study Site	Study Site Set-up -2
4. If necessary, build an instrument shelter	Study Site Set-up -3
5. Install the instrument shelter at the site	Study Site Set-up -1
6. Install and calibrate the digital thermometer and send set-up information to GLOBE	- Calibrate the calibrating thermometer: Study Site Set-up -4 - Place the digital thermometer in the instrument shelter, but do not sink the soil probe into the ground: Study Site Set-up -5 - Calibrate both of the probes for the digital thermometer: Study Site Set-up -8 - Sink the soil probe into the soil: Study Site Set-up -5 - Reset the digital thermometer: Study Site Set-up -6
7. If you have a rain gauge, install the rain gauge at the study site	Study Site Set-up -10
8. If you are ever having trouble with the digital thermometer or have to change out the battery, perform a soil sensor error check	Study Site Set-up -7 Study Site Set-up -9

Choosing an Atmosphere Study Site and Installing the Instrument Shelter

Study Site Set-up – 1

Materials / Preparation:

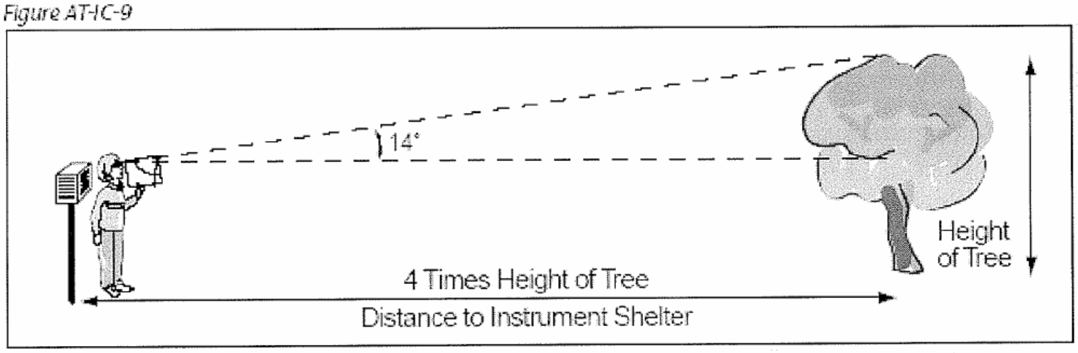
- ❑ Tape measure for initial site consideration
- ❑ Clinometer *(See clinometer construction below)*
- ❑ Materials to make a simple clinometer
  - Clinometer facing sheet *(attached below)*
  - A piece of cardboard a little bit bigger than a piece of notebook paper
  - A piece of nylon or cotton string, 25 cm long.
  - The empty tube of a ballpoint pin
  - A washer, a coin, an old key…something metal that can be hung from the string to add a little weight to it

To Do:

Site Selection

1. Your study site should be free of obstacles (walls, buildings, tall trees) for at least 10m in any direction and should have a clear, non-obstructed view of the sky. Furthermore, Atmosphere measurements are taken frequently, so students need to be able to get to the site and return in a short amount of time.
2. The choice of your atmospheric study site and the correct installation of your instrument shelter (and rain gauge if you have one) are critical to your successful implementation of this investigation.
3. The ideal site for taking atmospheric measurements is open—away from trees, buildings and other structures. An open area is important so that nothing blocks precipitation creating rain or snow shadows, air is free to flow around the instruments, heat from individual buildings doesn't affect the data significantly, and most of the sky can be seen.
4. In choosing your site, some compromise may be necessary between the ideal for scientific observations and the logistical constraints of the school grounds and their surroundings. This is OK; the key to ensuring the value of your students' data is to document the nature of your Atmosphere Study Site and its surroundings.
5. How to check that a proposed study site is open enough: Stand at the proposed site of installation and look through your clinometer at the tops of all nearby objects. The clinometer, when read by your partner, should show an angle of no more than 14˚. Any object that is greater than 14˚ will need to be recorded during the documentation of your study site. The picture on the following page demonstrates the clinometers use at an ideal site:

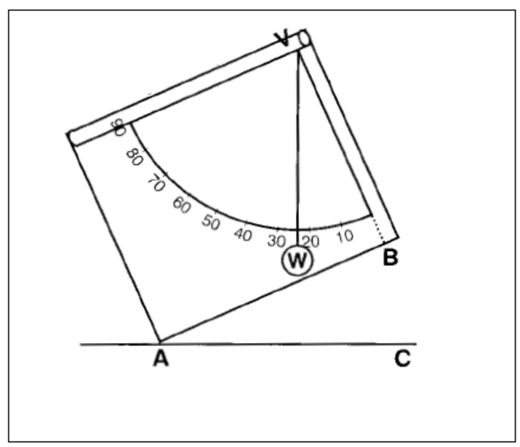
Figure AT-IC-9



6. Trees, buildings, and other structures are all at least four times as far away as they are tall. For example, if your site is surrounded by trees or buildings that are 10 meters tall, place your instruments at least 40 meters from these trees. At such distances, trees, bushes, or buildings can be useful by breaking the wind and actually make your rainfall and snowfall readings more accurate. Also, all buildings and walls should be at least 10 m from the instrument shelter.

Building a Clinometer

Note: If you don't have access to a photocopier, see the modified clinometer lessons in the Trees & Wood appendices for other construction options.



1. A **clinometer** is a simple tool to measure the slope of the ground (or in other cases, the height of a given object).
2. Paste or tape a copy of the clinometer *(below)* on the piece of cardboard. Make sure that the two are about the same size.
3. Punch a hole through the circle marked on the paper. Pass a 25 cm piece of string through the hole and attach its end on the back side of the cardboard.
4. With more scotch tape or a knot, attach a nut, a washer, or a coin at the other end of the string in such a way that the washer can slide back and forth across the surface of the cardboard without getting caught up on its edges.
5. Tape a drinking straw or an empty ballpoint pen tube along the line marked on the paper. Be sure the scotch tape doesn't get in the way of the ends of the straw or pen tube.

Considerations for the Positioning of the Instrument Shelter and Thermometer

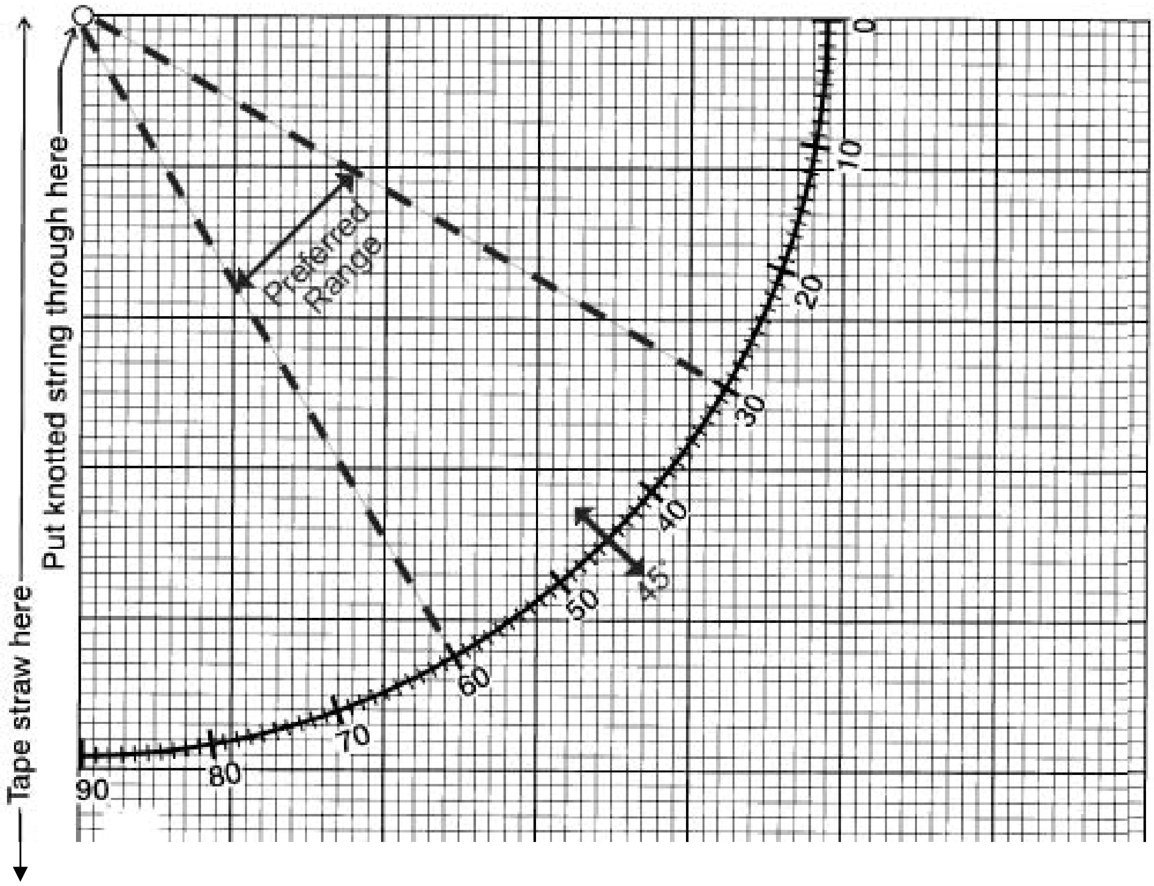
Note: This is just an overview of the set-up process. For more detailed instructions, see Study Site Set-up sections 5, 6, and 8.

1. The instrument shelter should be mounted such that the maximum-minimum thermometer mounted inside is 1.5 meters above the ground. This will help prevent heat from the ground from affecting your temperature reading. The instrument shelter should be mounted on the north side of the post. This placement helps protect the thermometer from direct sunlight when the shelter door is opened to take a reading.
2. The post on which the instrument shelter is mounted should be secured in the ground as firmly as possible. This will help minimize vibrations caused by strong winds which may cause the sensors of the maximum/minimum thermometer to move up against a wall of the instrument shelter and skew measurements.
3. Prolong the life of the mounting post by coating it in old motor oil before sinking it into the ground in order to discourage insects and decay.
4. Mount the maximum/minimum thermometer in the instrument shelter so that there is air flow all around the thermometer case. This is usually accomplished by using blocks or spacers between the thermometer and the rear wall of the shelter. See the figure below. No part of the thermometer should touch the walls, floor, or ceiling of the shelter.
5. The probe of the digital multi-day maximum/minimum thermometer should hang in the air inside the shelter and should not be touching any of the walls.

Security of Your Instruments

1. Some schools have reported vandalism problems at their GLOBE study sites, particularly with the rain gauge and the instrument shelter. Each school must determine what security measures work best for them. Some schools place their instrument shelter in a very prominent place where the whole community can appreciate it and keep a watch on it. Other schools have put fences around their atmosphere sites. This is perfectly acceptable, providing that the fencing does not interfere in any way with the instruments. This means that a fenced enclosure must be large enough so that the rain gauge is completely free from obstruction. In this case, it would be best to mount the rain gauge on the instrument shelter post.

Clinometer



Tape straw here
Put knotted string through here
Preferred Range
0
10
20
30
40
45°
50
60
70
80
90

Documenting Your Atmosphere Study Site

Study Site Set-up – 2

Materials / Preparations:

- 50 m measuring tape
- Clinometer (*See Study Site Set-up 1 for clinometer instructions*)
- Atmosphere Site Definition Sheet *(below)*
- Compass* *(ask to borrow one from a GLOBE representative if you do not have one)*
- GPS receiver* *(ask a GLOBE representative)*
- Digital camera* *(ask a GLOBE representative)*

**You can start the documentation process without these instruments.*

To Do:

1. To start reporting atmosphere measurements to GLOBE, you must define your Atmosphere Study Site in the GLOBE data system.
2. To enable your students to get a quick start, you may initially define the site by giving it a name and assigning it the same coordinates as your school location. Later, when you have measured the latitude, longitude, and elevation using a GPS receiver, you can edit the study site definition to supply this information.
3. There are many other characteristics of your study site which may be important to various data users; these include the heights of your rain gauge, maximum/minimum thermometer, the slope at your site and the slope's direction, and any ways in which your site differs from ideal conditions. It is important that you report as much of this information as you can to GLOBE when you are uploading your data.
4. At many GLOBE schools the ideal atmosphere study site doesn't exist. Scientists can still make good use of the data from these schools, but information is needed about all the ways in which your site is not ideal. This information is called **metadata** and is reported as part of the Atmosphere Study Site definition. It is important for scientists to know any local conditions which could affect the temperature at the instrument shelter, the amount of rain reaching the rain gage, the ability of students to see the whole sky, etc.

Fill out the Data Sheet

1. Fill in the information on the top of your Atmosphere Site Definition Sheet.
2. Measure the latitude, longitude, and elevation of the site with a GPS system and record this information on the Atmosphere Site Definition Sheet.

   Note: You can skip this step until a GLOBE representative comes to visit your school. When needed, GPS instructions are in the appendices of the Atmosphere module.)

3. Describe all obstacles surrounding your site. A building, tree, etc. is considered an obstacle if, when you sight its top through a clinometer, it has an angle > 14°.

4. Describe any buildings or walls closer than 10 meters to your installation site.
5. If you recorded any trees or buildings in steps 3 or 4, take photographs of the surroundings of your site looking North, East, South, and West. Number each photo digitally or with a pen on the back of the prints and record each number next to its corresponding cardinal direction on your Atmosphere Site Definition Sheet.

   Note: If you don't have a camera, you can wait on this step until a GLOBE representative can come to your site.

Measure the Slope and Aspect

1. Choose a partner whose eyes are at the same height as yours.
2. Ask them to stand 5 meters away from you going up hill on the steepest slope at your site.
3. Look at their eyes through the clinometer and have another person note the angle indicated by the clinometer. This is the slope at your site. Record this on the Atmosphere Site Definition Sheet.
4. Without either you or your partner moving, hold a compass so that the red needle aligns with the N on its housing. Then, take a bearing for the direction that your partner is standing. That is to say, read the number on the compass that points towards your partner when the compass needle is pointing north. Record this compass direction (bearing) on the Atmosphere Site Definition Sheet. *(If you don't have a compass, you can borrow one from a GLOBE representative or wait on this step until a GLOBE representative can come to your site.)*

For the Instruments That You Have Installed (see following protocols):

1. Measure and record the height of the top of the rain gauge above the ground in centimeters.
2. Measure and record the height of the sensor of the maximum-minimum thermometer above the ground in centimeters.
3. Record the type of ground cover that is under the instrument shelter.

Atmosphere Site Definition Sheet

School Name: ___________________________Class or Group Name: __________________
Name(s) of student(s) filling in Site Definition Sheet: _________________________________

____

Date: __________________________ Check one: ❐ New Site ❐ Metadata Update
Site name (give your site a unique name):____

Location: Latitude: ____________° ❐ N or ❐ S Longitude: ____________° ❐ E or ❐ W
Elevation: ___ meters
Source of Location Data (check one): ❐ GPS ❐ Other _______________________________

Obstacles (Check one): ❐ No obstacles ❐ Obstacles (describe below)
(Obstacles are trees, buildings, etc. that appear above 14° elevation when viewed from the site)
Description:____

____

____

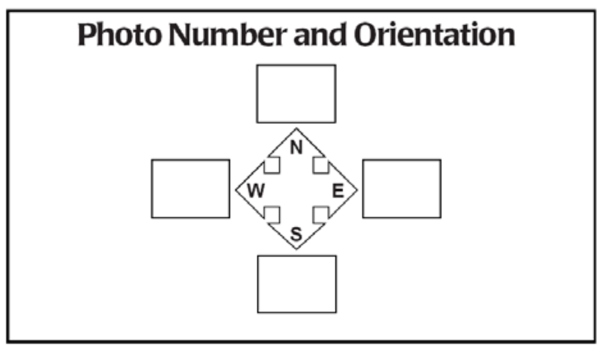
Buildings within 10m of your instrument shelter (Check one): ❐ No buildings ❐ Buildings
Description of any Buildings:

____

____

____

____



Other Site Data:
Steepest Slope: ___________________
Compass Angle (facing up slope): ___-
____
Height of the top of the rain gauge: _________ cm
Height of the sensor or bulb of your max/min thermometer: _________cm
Height of the clip in your ozone measurement station: _________cm
Surface Cover under instrument shelter (Check one): ❐ Pavement ❐ Bare ground
❐ Short grass (< 10 cm) ❐ Long grass (> 10 cm) ❐ Sand ❐ Roof (describe below)
❐ Other (describe below)
Description:____

____

Overall comments on the site metadata):____

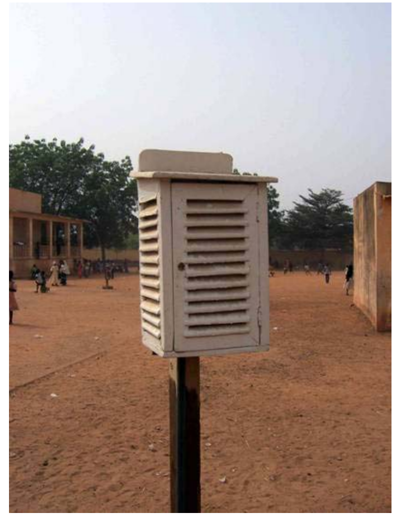
____

____

____

Constructing your Instrument Shelter

Study Site Set-up – 3

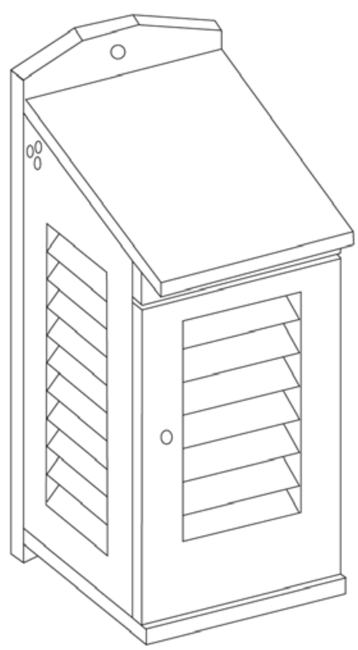


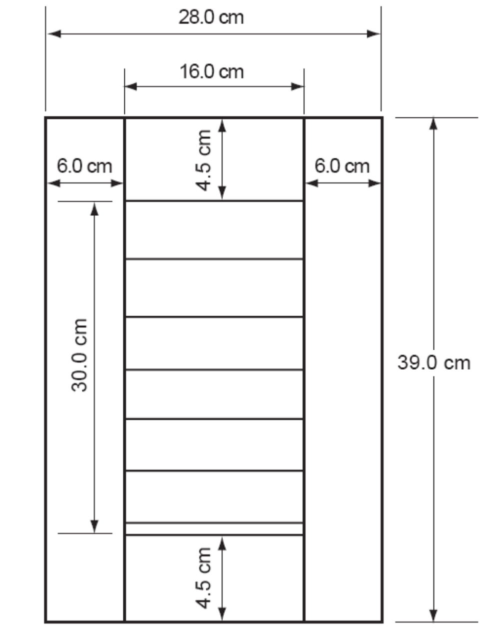
Materials / Preparations:

- Instructions/drawing of the instrument shelter *(below)*
- Source of funding

To Do:

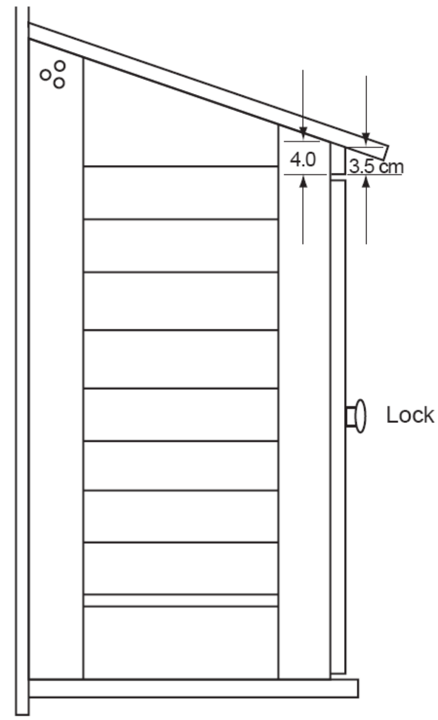
1. The GLOBE Instrument Shelter should be constructed of approximately 2 cm thick White Pine or similar light wood and painted white, inside and out.
2. A lock should be installed to prevent tampering with the instruments.
3. Mounting blocks should be installed on the interior to insure that the max/min thermometer does not touch the back wall.
4. The walls of the instrument shelter should be screwed together or glued and nailed.
5. The plans are specified in metric units. Therefore, you may need to make minor adjustments to dimensions depending on the local standard dimensions of wood in your region.
6. The primary criteria for constructing "shutter-style" side vents are that they provide for ventilation of the instrument shelter while preventing sunlight and rain from entering and directly hitting the instruments. To prevent sunlight from entering the shelter we suggest that each slat of a vent overlap slightly with adjacent slats (See figure below). There should also be a gap between slats of approximately 1 cm, and the slat angle should be roughly 50-60 degrees from horizontal.
7. A good carpenter can make the instrument shelter and supply the post for no more than 20,000 CFA, probably less.



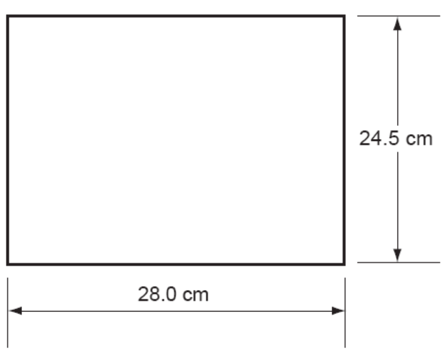


Front Door

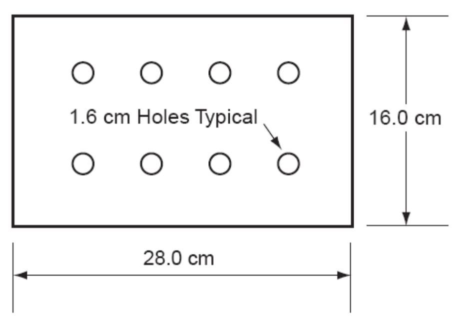
Note: Louvres are 0.64 cm Thick and 4.5 cm Wide



Side View

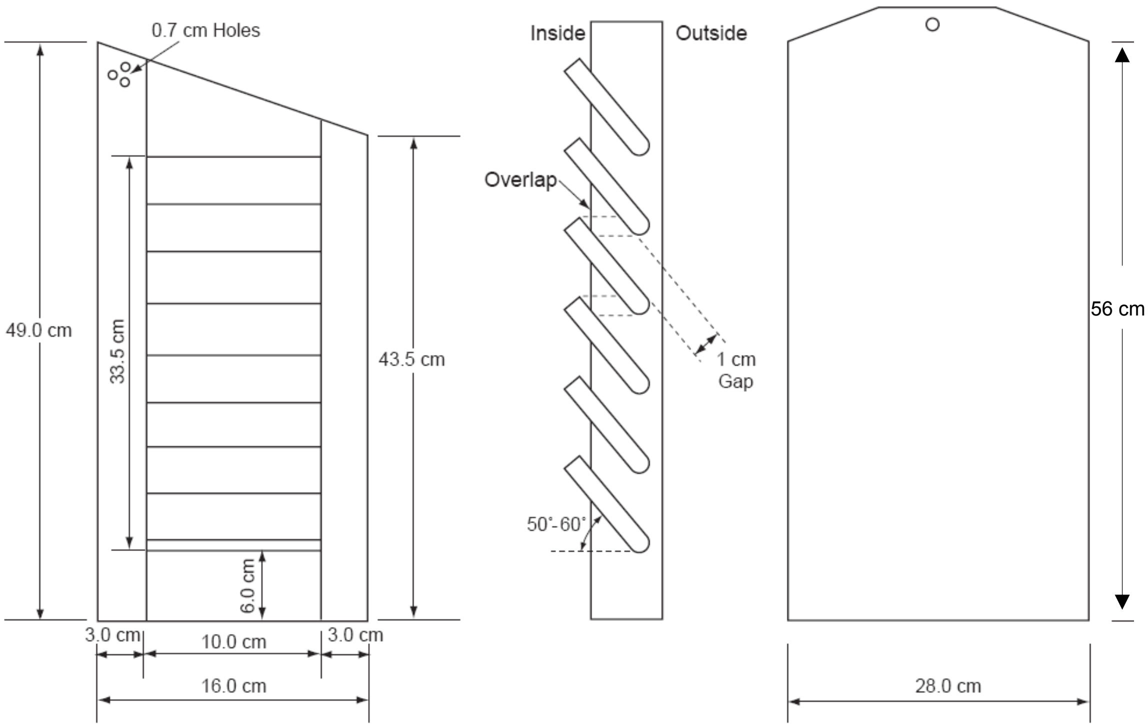


Roof

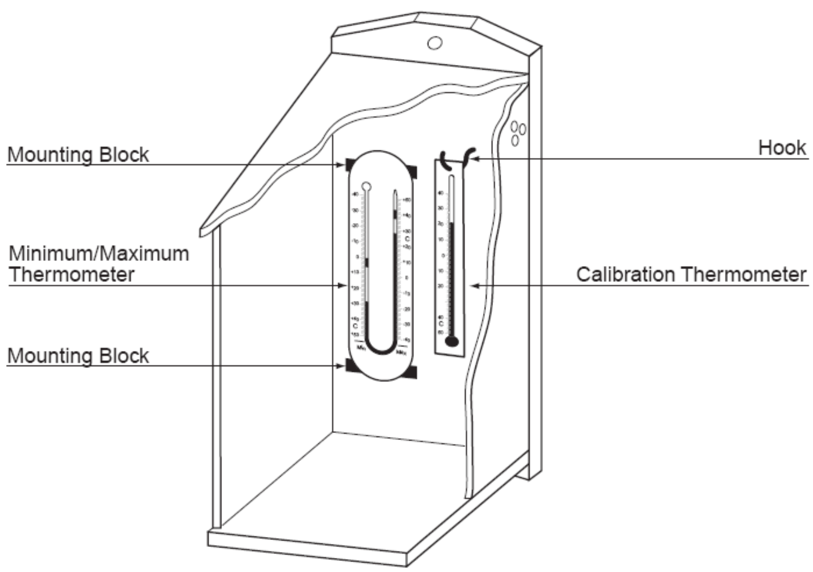


Bottom

Outer Dimension Inclusive of Louvre Panels



Side Panel Louvre Detail Back



Calibrating the Calibration Thermometer

Study Site Set-up – 4

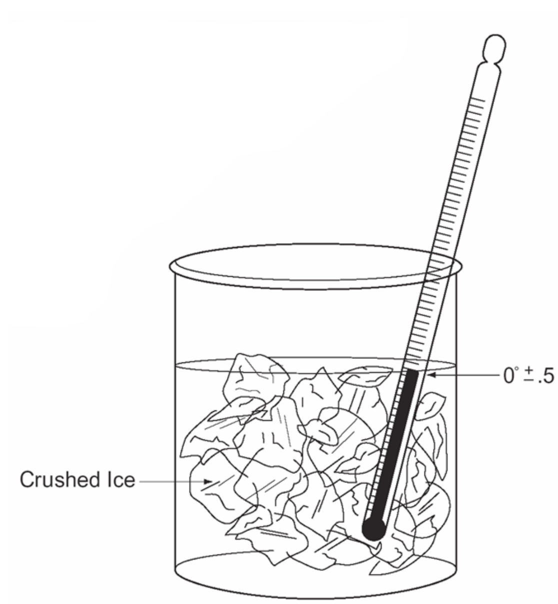
Materials / Preparations:

- Calibration thermometer (a liquid thermometer with an accuracy of at least 0.5°C)
- Crushed ice
- A clean container of at least 250 ml
- Water *(distilled is ideal, but the key is that the water is not salty)*

  Note*: In Niger, the round bottles labeled distilled water from Côte d'Ivoire are not distilled water and are less pure than the tap water here. Also, the battery shops in Niamey claiming to have distilled water actually only have filtered water from the Caterpillar machine shop. The only true distilled water that we have identified in Niger is the locally made distilled water from CNES (20.72.39.23) in the square plastic bottles. The Total gas stations around town usually carry CNES distilled water but the OiLibya stations do not.*

To Do:

1. Prepare a mixture of fresh water and crushed ice with more ice than water in your container.
2. Put the calibration thermometer into the ice-water bath. The bulb of the thermometer must be completely submerged in the water.
3. Allow the ice-water bath and thermometer to sit for 10 to 15 minutes.
4. Gently move the thermometer around in the ice-water bath so that it will be thoroughly cooled.
5. Read the thermometer. If it reads between -0.5° C and +0.5° C, the thermometer is calibrated.
6. If the thermometer reads greater than +0.5° C, check to make sure that there is more ice than water in your ice-water bath. Fix the problem and repeat steps 3-5.
7. If the thermometer reads less than -0.5° C, there might be salt in your ice-water bath. Dump out the mixture, wash the container well and repeat steps 1-5 with clean water.
8. If the thermometer still does not read between -0.5° C and +0.5° C, replace the thermometer. If you have used this thermometer for measurements report this to GLOBE.



Installing the Digital Thermometer

Study Site Set-up – 5 (Do in conjunction with Study Site Set-up – 6 and 8)

Materials / Preparations

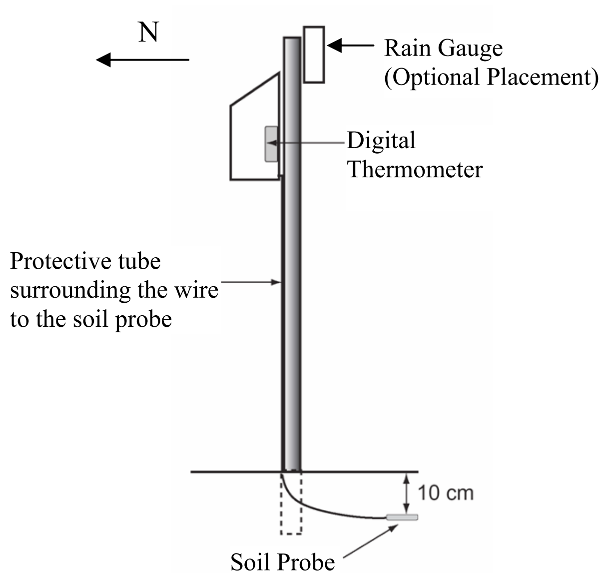
- Digging tools
- Plastic or wire ties to attach the protective tubing to the post
- GLOBE instrument shelter, already installed
- 120 cm x 2.5 cm pipe or tube to protect the wire of the soil sensor
- 3 nails or screws
- Calibration thermometer
- Time of solar noon for your location on the date that you plan to reset your digital thermometer (available on the internet or from a local weather service)

To Do:

1. Mount the digital thermometer housing to the rear wall of your instrument shelter. The housing should be placed so that the digital display may be read easily.
2. Hang the probe labeled “Left Sensor” from a nail placed in the roof of the instrument shelter so that no part of the probe can contact a wall and there is airflow all around it.
3. Calibrate the probes by following Study Site Set-up – Activity 8.

   Continue only if you have calibrated both temperature probes (Study Site Set-up 8).

4. Pass the soil sensor labeled “Right Sensor” through the hole in the floor of the instrument shelter and also through the protective tubing. Attach the tube to the post between the shelter and the ground with wire ties or another secure method.
5. Place the soil sensor horizontally in a hole that is 11 cm deep on the south side of the instrument shelter.
6. Refill the hole with the soil that you removed. Do not cover the sensor’s location with a rock or pack the soil too tightly on top of the sensor.
7. Neatly secure all extra cable for the soil sensor inside the instrument shelter using string or wire ties. Keep as much of the excess cable as possible within the shelter.
8. Close the thermometer cover and the door of the instrument shelter and wait until solar noon to reset the digital thermometer (Study Site Set-up 6) and complete your installation.



Resetting the Digital Thermometer

Study Site Set-up – 6

Materials / Preparations:

- The digital thermometer installed in the instrument shelter
- Pen or nail
- Digital Max/Min Thermometer Calibration and Reset Data Sheet (*below*)
- A digital watch or other method of accurately telling time

To Do:

1. After you have installed the digital thermometer, changed its battery, or have had another interruption of power, you will have to reset the digital thermometer.
2. Determine an appropriate time of reset that corresponds to the average time of local solar noon for your area. It is important that the time of reset is within one hour of local solar noon. You can obtain this time via the internet or another source of weather data.

   <u>Note</u>: Solar noon is not necessarily noon on your watch depending on the season and where you are located within your time zone, so you must look it up before proceeding.

3. Go to the instrument shelter a little before solar noon and open up the instrument shelter and the cover flap of the digital max/min thermometer.
4. At solar noon, use a nail or the tip of a pen to press in and release the reset button, located as shown above.
5. The digital display screen will briefly flash and then begin reading the current temperature. The instrument has now been reset. Record the exact time of day, in the Time of Reset section of the Digital Max/Min Thermometer Calibration and Reset Data Sheet. This is your **<u>time of reset</u>**.
6. Report your time of reset and the date to GLOBE in both local and universal time (UT).
7. Proceed to Study Site Set-up – 8, Digital Thermometer Sensor Calibration to complete the data sheet.

Digital Max/Min Thermometer Calibration and Reset Data Sheet

School Name: ____________________________________ Study Site: ATM-___________

Observer Names: ____

Date: Year ______ Month ______ Day ______

Time of Reset

Note: The thermometer should be reset only when it is first setup, after the battery is changed, or if the time of local solar noon drifts to more than one hour from your time of reset.

Local time: __________ Universal time __________

Was the reset due to a battery change? ________

Calibration Thermometer Readings

Thermometer readings						
Reading n°	**Date (Day / Month/ Year)**	**Local Time**	**Universal time**	**Calibrating thermometer's temperature (C°)**	**Air sensor's temperature (C°)**	**Soil sensor's temperature (C°)**
1						
2						
3						
4						
5						

Digital Thermometer Soil Sensor Error Check

Study Site Set-up – 7

Materials / Preparations:

- Digital thermometer with soil sensor
- Soil thermometer or calibration thermometer
- Soil Sensor Error Check *(below)*

To Do:

1. Open the door of the instrument shelter.
2. Select a place about 15 cm from the location of the soil temperature probe.
3. Measure the soil temperature at a depth of 10 cm at this spot using a soil thermometer following the instructions for its use found in the Soil Protocol.

   Note: *If you do not have a soil thermometer, try the following procedure:*
   a. *Hammer a piece of rebar in the ground to a depth of 11 cm. Try not to disturb the soil more than necessary.*
   b. *Remove the rebar and put the calibration thermometer in the hole. Do not force the thermometer or it may get damaged.*
   c. *Lightly cover the rest of the thermometer with a little soil, and cover the calibration thermometer and soil above the buried temperature sensor with a temporary shade cover that doesn't impede air circulation.*
   d. *Wait at least one hour before taking the data following the method described in the instructions for the soil thermometer.*

4. Record this temperature on the data sheet.
5. Take the current temperature of the soil temperature by pushing the right-hand ON button that corresponds with the buried sensor. Note the temperature.
6. Repeat steps 2 to 8 four more times, waiting one hour between measurements.
7. Calculate the average of the soil calibration thermometer readings.
8. Calculate the average of the digital soil sensor readings.
9. Calculate the soil sensor error by subtracting the average of the five digital soil sensor readings from the average of the five soil sensor readings.
10. If the absolute value of the soil sensor error is greater than or equal to two 2° C, then dig-out this sensor and recalibrate both the air and soil sensors according to the calibration instructions. Otherwise leave the digital soil sensor in the ground and recalibrate only the air sensor.

Digital Soil Sensor Error Check Data Sheet

Name of School: ____________________ Date: ____________________________

Thermometer Readings					
Reading n°	**Date (Day / month/ year)**	**Local Time**	**Universal Time**	**Reading from the soil thermometer (C°)**	**Reading from the digital soil sensor (C°)**
1					
2					
3					
4					
5					
Total of the five readings [1] :					
Average of the five readings [2] :					
Soil sensor error [3] : (= average in column 2 – average in column 1)					

1: Add together the five temperatures taken from each thermometer.

2: Average of the five readings taken from the soil thermometer = the sum of the five readings taken from the soil thermometer divided by five
Average of the five readings taken from the digital soil sensor =the sum of the five reading taken from the digital sensor divided by five.

3: Soil sensor error = the digital soil sensor's average minus the soil thermometer's average

If the absolute value of the soil sensor error (#5) is greater than or equal to 2˚ C, then dig-out the sensor and recalibrate both the air and soil sensor following the instructions for Digital Multi-Day Max/Min Thermometer Sensor Calibration. If the absolute value of the soil sensor error that you calculate is less than 2˚ C then leave the soil sensor buried and proceed to recalibrate just the air sensor.

Digital Thermometer Sensor Calibration

Study Site Set-up – 8

Materials / Preparations:

- Calibration thermometer that has already been checked for accuracy *(Study Site Set-up – 4)*
- Digital thermometer
- Digital Max/Min Thermometer Calibration and Reset Data Sheet *(following Study Site Set-up – 6)*

To Do:

1. Open the door to the instrument shelter and hang the calibration thermometer and the two probes, both air and soil, from nails in the top of the instrument shelter so that they have air flow all around them and do not contact the sides of the shelter. Close the door to the instrument shelter.
2. Wait at least an hour and then open the door to the instrument shelter. Read the temperature from the calibration thermometer and record it to the nearest 0.5° C on your Digital Max/Min Thermometer Calibration and Reset Data Sheet.
3. Turn on the air temperature display of the digital multi-day max/min thermometer by pressing the air sensor ON button (upper left button). Read and record the current air temperature.
4. Turn on the soil temperature display of the digital multi-day max/min thermometer by pressing the soil sensor ON button (upper right button). Read and record the current soil temperature.
5. Close the cover flap of the digital thermometer and the door of the instrument shelter.
6. Repeat steps 2 to 5 four more times, waiting at least one hour between each set of readings. Try to space out the five sets of readings over as much of the day as possible.
7. Report your calibration data to GLOBE.

Changing the Battery in the Digital Thermometer

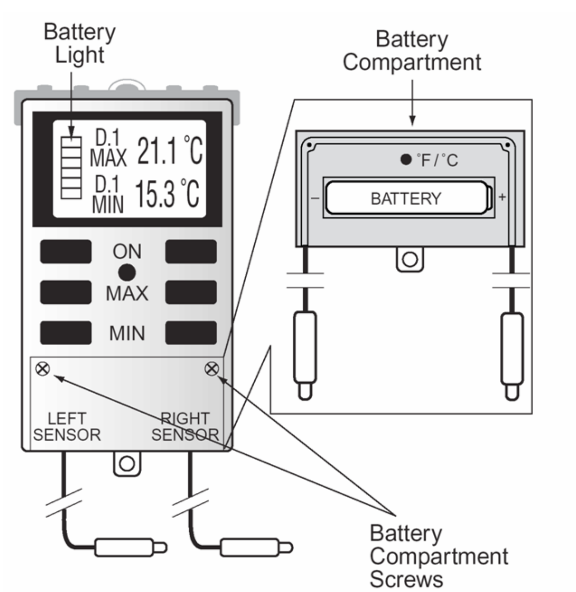
Study Site Set-up – 9

Materials / Preparations:

- A new AA battery (usually AA but may be D)
- A small Phillips head screwdriver

To Do:

1. The battery is in the battery compartment in the lower section of the instrument casing.
2. Remove the two little screws located at the upper corners of the compartment cover and lift off the cover.
3. Change the battery, taking care to ensure correct polarity (negative end of battery contacting the spring).
4. Replace the compartment cover and secure with the two screws. After the battery has been changed be sure to recalibrate the instrument.
5. Reset the instrument using the guide “Resetting of a Digital Thermometer” (Study Site Set-up – 6)
6. Recalibrate the air and soil sensors following the guides “Digital Thermometer Soil Sensor Error Check” (Study Site Set-up 7) and “Digital Thermometer Sensor Calibration” (Study Site Set-up – 8).



Installing (and Constructing) a Rain Gauge

Study Site Set-up – 10

Materials / Preparations:

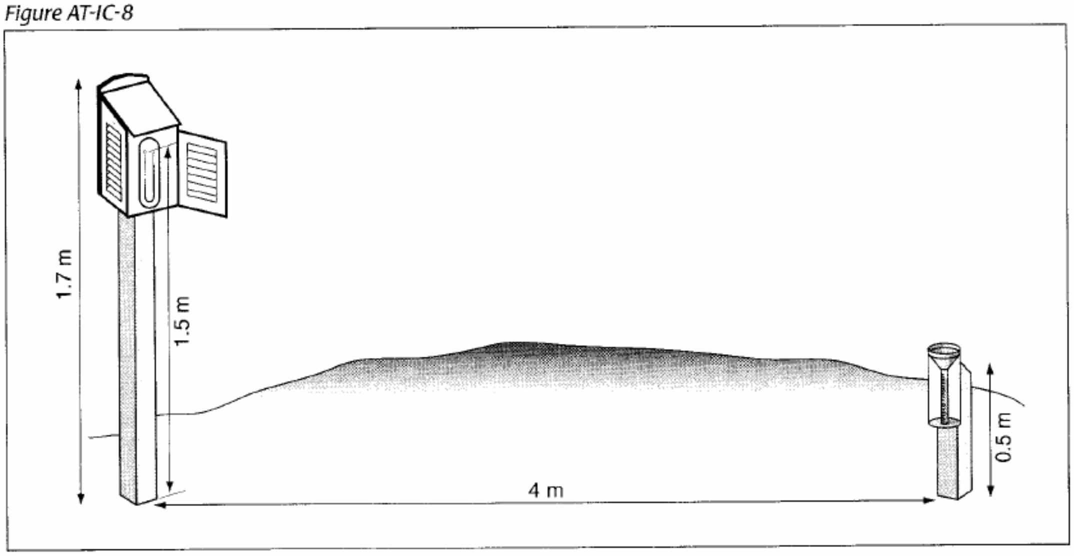
- Rain Gauge *(if you don't have one, make one by following the instructions below)*
- Post at least 0.75 m long
- Some used motor oil with which to coat the post in order to slow the arrival of insects and rot
- Tools and materials for fixing the rain gauge to the post and placing the post into the ground

To Do:

Positioning the Rain Gauge

1. Since wind is one of the greatest causes of error in rain gauge measurements, the best placement for the rain gauge is on a post as low to the ground as practical. The top of the rain gauge should be about 0.5 meters above the ground and be located 4.0 meters away from the instrument shelter so that the shelter does not block rain from collecting in the gauge.

Figure AT-IC-8



2. Make sure the top of the rain gauge is about 10 cm above the top of the post, to avoid splash-in of rain from the post's top. If possible, cut the top of the post at a 45° angle sloping away from the rain gauge so that drops will splash away from the gauge.
3. If it is not practical to place the rain gauge and instrument shelter on separate posts, they may be mounted on a single post, with the rain gauge mounted on the opposite side from the shelter and following the instructions above for its placement in relation to the highest part of the post and instrument shelter ensemble.

Constructing a Rain Gauge

1. If you can acquire a graduated cylinder but you don't have a rain gauge, you can make the rain gauge yourself.
2. Find a rather deep container with straight sides to use as a rain gauge. Two large tomato paste cans fixed one on top of the other with the bottom removed from the top can would work. A tinsmith can fix the two cans together for a nominal fee. Attach it to the top of a post or on another flat object raised off the ground about 0.5 m. Make sure that you can remove the rain gauge to dump out its contents for measurement.

   Now, to calculate the depth of the rain that you have collected, you can use the following calculation:

   $$\text{Depth of the rain:} \quad = \quad \frac{\text{Volume of water in ml x 10}}{\text{Surface area of the container opening in cm}^2}$$

   Recall that the surface area of a circle = π x Radius^2

   $$\text{and the Radius} = \frac{\text{Diameter of the circle}}{2}$$

Introduction to GLOBE and to the Atmosphere

Materials and Preparations:

- Matches
- List of participating GLOBE countries *(below)*
- Map of the world or a globe *(if necessary, there is a small map below)*
- Students' GLOBE notebooks

Lesson Plan:

Classroom Introductions and Group Formation

1. Ask each student in the class to introduce himself to you and the rest by saying his or her name and an interesting fact about himself, for instance his favorite food.
2. Divide the students into groups of 5 or 6 to take data and do group work for the rest of the sessions. Give each group a name based on GLOBE countries, the levels of the atmosphere, or some other science-related theme.

Introduction to the GLOBE Program

1. Write the word "globe" on the board and ask the students "What is a globe?"
2. Explain that GLOBE is also the name of our program.
3. Explain that GLOBE is an acronym that stands for "Global Learning and Observations to Benefit the Environment." Write this on the board.
4. Explain that the program started in 1996. In the following 12 years it has grown and now encompasses over 7500 schools in 110 countries. The students of these schools have become scientists and they do real research on the environment. In addition, they share their data with environmental scientists and other schools around the world via the internet.
   a. Definition: The **internet** is a system of communication that allows computers around the world to share information with each other. It is like a cell phone network but for computers.
   b. Ask the students to raise their hands if they have used the internet before. Tell them that they can visit the GLOBE program at the following website: **www.globe.gov** and that it is open to anyone to use.
5. The Nigerien government invited the GLOBE Program into the country in 2005 and it is now part of the Ministry of Education and managed by the CGPE, La Cellule pour la Généralisation et Pérennisation de l'Éducation Environnementale.

Goals of the GLOBE Program

1. The GLOBE Program has two linked objectives, **science** and **education**.
2. At out level, the program has the goal of helping you to:
   - Become good scientists
   - Better understand your environment
   - Understand the scientific method

- Use scientific instruments
- Take measurements and analyze them
- Use the internet to make your data available to students and scientists around the world, and
- Create links between science, math, technology, and the environment.

3. GLOBE student scientists study 5 aspects of their environment
   - Atmosphere
   - Water
   - Soil
   - Land cover (vegetation)
   - Seasonal changes
4. We will start with the study of the atmosphere. But first, let's play a game.

Game: Discovering GLOBE Countries around the World

1. Divide the class into teams. Tell each team to take out a blank sheet of paper.
2. Explain that GLOBE is in many countries on all of the continents.
3. Explain that you will light 2 matches in succession.
4. During the time that they burn, each team should try to write down as many country names as they can.
5. Once the second match goes out, tell the teams to stop writing and have them recopy their answers onto the blackboard. Circle the names of all the countries that host the GLOBE Program.
6. Each team earns a point for each GLOBE country that they wrote down.
7. Play a second time, but first explain that the students cannot write down or gain points for any of the countries that are already written on the blackboard.
8. After you have played a few times, add up the score and announce the winner.
9. Leave the names of the GLOBE countries on the board and ask if any students have thought of any others, and write these on the board too.
10. Show them the locations of each country that they named on a globe or on a map of the world. *(If needed, there is a small map below)*
11. ***Modification 1***: Each time that you play this game in class, show the students 5 or 6 GLOBE countries on a globe or map that they do not know. Then, in playing this game several times during the school year, the students will slowly learn many of the world's countries.
12. ***Modification 2***: Give each team a copy of the map below. Then, say the name of a country and each team attempts to place a finger on the country on their map. Give a point to each team that correctly responds and correct each team that does not.

Introduction to the Atmosphere

1. Definition: The **atmosphere** is the layer of air that covers the Earth. It has a thickness of over 1000 km.
2. The different layers of the atmosphere:
   - Troposphere: from sea level up to 12000 meters in elevation
   - Stratosphere: from 12000 to 50000 meters above sea level
   - Mesosphere: from 50000 to 85000 meters above seal level
   - Thermosphere: over 85000 meters above sea level
3. Some facts about each layer of the atmosphere:
   a. **Troposphere:** This layer produces the majority of weather (clouds, rain, snow, wind…) that influences the existence of living things. This layer is also most used by planes.

b. **Stratosphere:** This layer filters out many of the sun's harmful solar rays thanks to a gas in this layer called **ozone** (three oxygen atoms fixed together, O_3). It protects living things from these destructive solar rays that would otherwise scorch the surface of the earth.
c. **Mesosphere:** This layer is responsible for the formation of **shooting stars**, which are small pieces of rock or dust that burn as they pass through the atmosphere.
d. **Thermosphere**: Because this layer is the first to be heated by the sun's rays, the air in this layer can reach temperatures over 1500˚C. Its outer part is called the **ionosphere**.

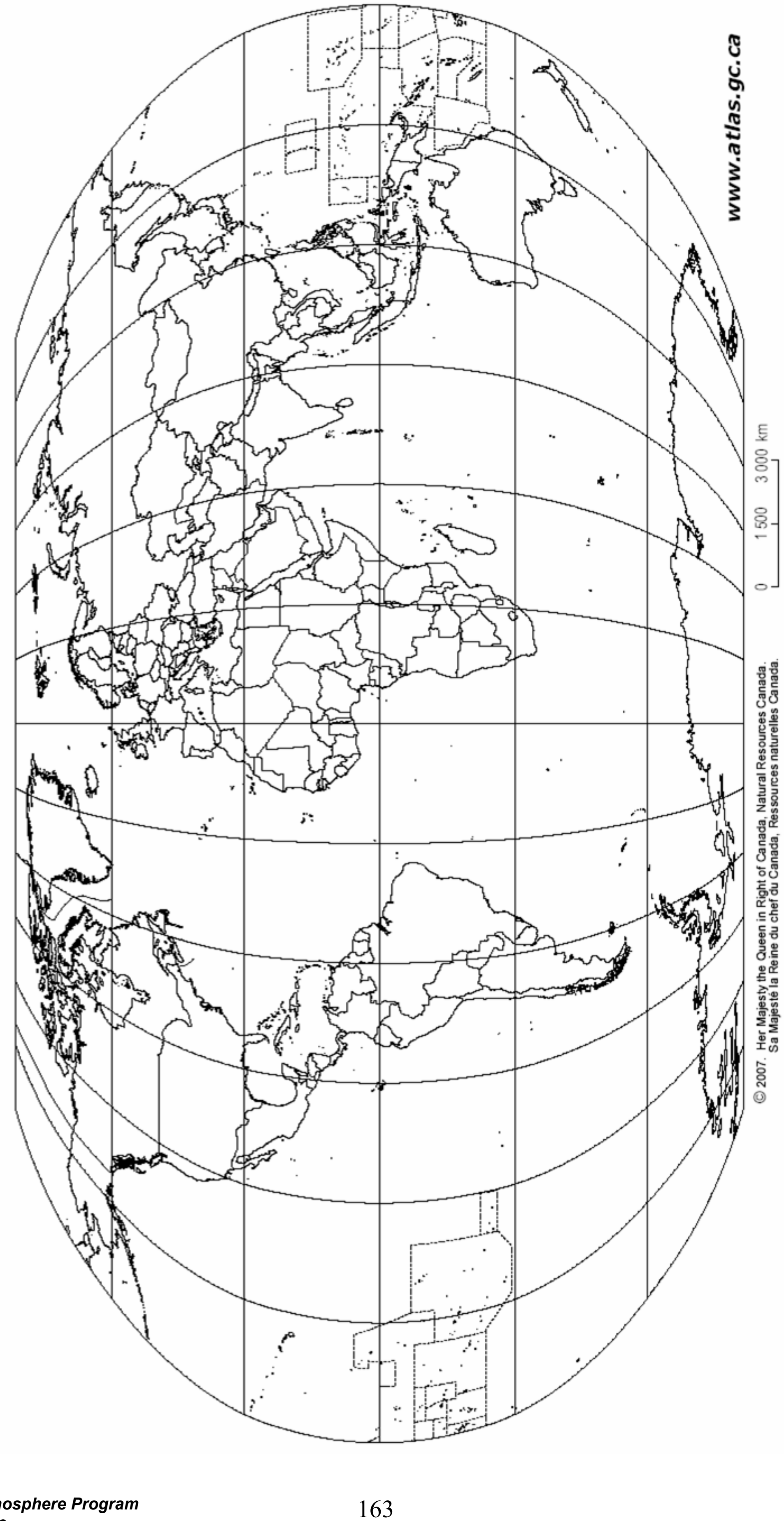
Review Strategy: Linked Words or Phrases

1. Instead of only reading their notebook over and over to memorize facts, another method that students can use is the creation of **linked words or phrases**. These phrases are used to memorize the items or the order of the items of a list. Here is the methodology:
2. First, take the first letter of each word in the list.
3. Then, create a phrase based on these letters—using each letter as the start of a new word. In this way, you create a memorization aid, for you now have the first letter of each word in the list.
    - **Example**: A vector in Math or a force in Physics has four characteristics: **P**oint of application, **S**ense, **L**ength, and **D**irection. So, take the first letters: **P,S,L,D** and construct a phrase like: **Please Shout Loudly Dummy!**
4. Now, each time that one forgets the four characteristics, one only needs to repeat the linked phrase to remember the first letter of each word as a way to help you remember the whole word.
    - **Example 2**: The layers of the atmosphere: **T**roposphere, **S**tratosphere, **M**esosphere, and **T**hermosphere. So, we have **TSMT**: **The Sky's Many Tiers**
5. Optional Practice: Ask the students to create sentences themselves from new lists that the teacher generates or better yet, from a list that they have in their notebooks for another subject.

GLOBE Countries of the World

Argentina
Australia
Austria
Bahamas
Bahrain
Bangladesh
Belgium
Benin
Bolivia
Bulgaria
Burkina Faso
Cameroon
Canada
Cape Verde
Chad
Chile
Colombia
Congo
Costa Rica
Croatia
Cyprus
Czech Republic
Denmark
Dominican Republic
Ecuador
Egypt
El Salvador
Estonia
Ethiopia
Fiji
Finland
France
Gabon
Gambia
Germany
Ghana
Greece
Guatemala
Guinea
Honduras
Hungary
Iceland
India
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Korea, South
Kuwait
Kyrgyzstan
Latvia
Lebanon
Liechtenstein
Lithuania
Luxembourg
Macedonia
Madagascar
Maldives
Mali
Malta
Marshall Islands
Mauritania
Mexico
Micronesia
Moldova
Monaco
Mongolia
Morocco
Namibia
Nepal
Netherlands
New Zealand
Niger
Nigeria
Norway
Pakistan
Palau
Panama
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russia
Rwanda
Saudi Arabia
Senegal
Serbia and Montenegro
South Africa
Spain
Sri Lanka
Suriname
Sweden
Switzerland
Tanzania
Thailand
Trinidad and Tobago
Tunisia
Turkey
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States of America
Uruguay

THE WORLD / LE MONDE



Introduction to the Digital Thermometer

GLOBE Temperature – Lesson 1

Materials and Preparations:

- Digital thermometer
- Alcohol thermometer
- A large graph on paper that will be hung in the classroom for recording the data from the digital thermometer— horizontal axis: date; vertical axis: temperature *(old cement sacks work great)*
- Students' GLOBE notebooks

Lesson Plan:

Explanation (Review) of the Temperature Scale

1. Definition: **Temperature** is a relative measure of the quantity of heat that is in a body of matter.
2. You measure temperature with the aide of a thermometer in degrees Celsius.

Game: Estimating the Current Temperature

1. Ask each class group for an estimation of the current temperature and write each one on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimation.
2. Explain the importance of being able to make accurate estimations.
3. If you have not already done so during another session, have the students make other estimations as a competition between groups. For example, have each group estimate the height of various classroom objects. Then, ask a student to measure each object and give a point to the team who is closest. Play several rounds. One could also estimate the distance between objects in the classroom, the exact time, students' heights, etc.

   Note: *This exercise in estimation along with the estimation of yesterday's maximum and minimum temperatures will be used in the following lessons as the opening activity. Its intention is to train the students to make accurate estimates. However, it would also be good to switch often between this game and the GLOBE Countries of the World game to increase student learning on two things rather than just one.*

Explanation of the Digital Thermometer and How to Take Data from It

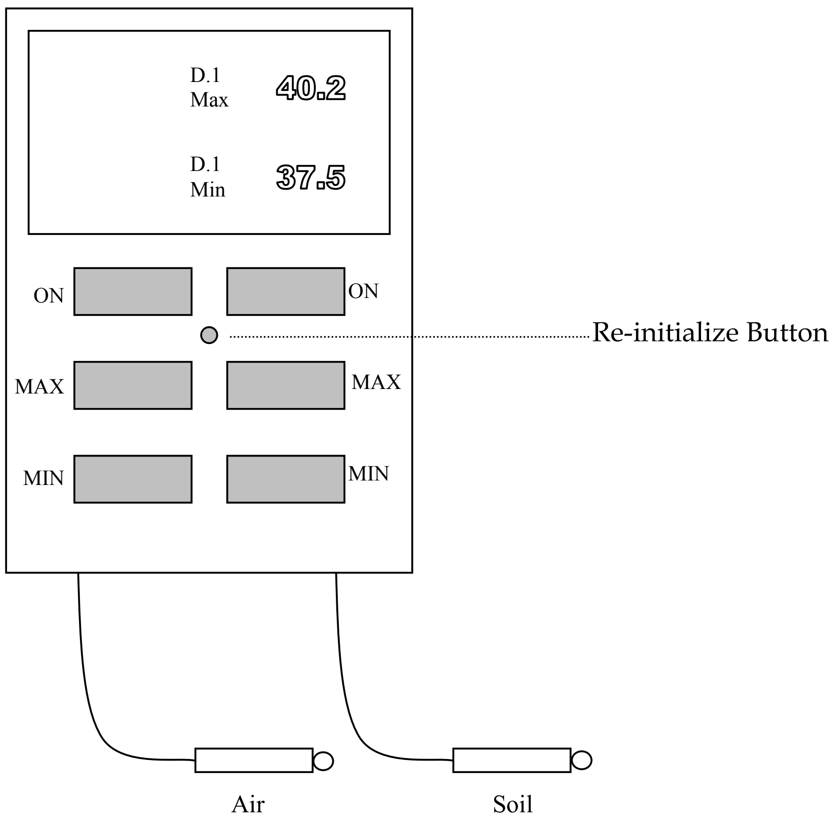
Note: *We encourage you to visit the digital thermometer with the students first for a hands-on explanation and then return to the classroom to take the following notes.*

1. Start this session with the definitions of different types of thermometers so the students can distinguish between them.

2. Say: Remember that we use a thermometer to find the temperature of a body of matter. There are several different types of thermometers:
    - An **alcohol** or **mercury thermometer** is a sealed tube of glass that contains a liquid in a reservoir and has a scale printed on its side. When the temperature changes, the liquid in the tube contracts or expands, as does all matter, and it moves along the scale, thus indicating a change in temperature.
    - A **digital thermometer** uses a sensor and electronics to measure the temperature instead of the dilation of a liquid.

3. Ask the students to recopy the image of a Digital Thermometer in their notebooks from the blackboard. Ask them to make their drawings rather large.

Digital Thermometer



4. Show the students the ON button
5. Show the students the MIN and MAX buttons and explain the MIN stands for the "minimum (lowest) temperature recorded during the whole day" and the MAX stands for the "maximum (highest) temperature recorded during the whole day".

Explaining How to Use the Digital Thermometer (Data Collection Procedure)

1. Record the time and date on the data sheet for the digital thermometer

   Note: Universal time, GMT, is one hour behind the local time here in Niger.

2. Light up the screen by pressing the ON button for the air sensor (the top left button)

   Note: The temperature that appears after the ON button is pressed once is the current temperature.

3. Push the MAX button two times (located in the middle of the left side)

   Note: the value that appears after the MAX button is first pushed represents the highest temperature recorded since the time the re-initialization button was first pushed and not for the past 24 hours. This value should not be recorded.

4. On the second push, the word MAX will appear on the screen along with the symbol **D.1** for "Day 1". Record this temperature on the data sheet.
5. Once again, press the MAX button and the D.1 will change to D.2 (for Day 2). Record this temperature. Repeat this step four more times to see the past six days' data (D.1-D.6)
6. To record the minimum temperatures, restart steps c through e by pressing on the MIN button (on the bottom left) instead of the MAX button.
7. For the soil temperatures, follow steps a-e but this time use the buttons on the RIGHT side of the instrument. For these temperatures, read the numbers that appear on the BOTTOM of the screen.
8. Once all of the data has been recorded, close the thermometer's cover. The screen will shut off automatically in a few minutes.

Correctly Recording the Data on the Data Sheet

1. If you take the data from the thermometer **before** the hour that you have initialized the thermometer (that is to say before solar noon) record your data from D.1 as the data for **yesterday**.
2. If you take data **after** the hour you have initialized the thermometer (after solar noon), record the value for D.1 as **today**.

Readings Taken AFTER Moment of Reset (recommended)

Digital Display			
Symbol:	D.1	D.2	D.3
Reading corresponds to:	Today	Yesterday	2 days ago

Readings Taken BEFORE Moment of Reset

Digital Display			
Symbol:	D.1	D.2	D.3
Reading corresponds to:	Yesterday	2 days ago	3 days ago

Practice

1. Ask the students to explain the steps that they have just learned to a partner. As they explain, they should push the buttons of the drawings in their notebooks. Make sure that each partner has a chance to explain the steps.
2. Then, call students to the board to explain the steps to the whole class using the "buttons" of the drawing of the thermometer on the blackboard.

Bi-weekly System of Data Collection

GLOBE Temperature – Lesson 2

Materials and Preparations:

- Alcohol thermometer
- Blank temperature graph
- Two handkerchiefs/bandanas
- Tape
- The names of each thermometer button written on separate and somewhat large pieces of paper. Do this twice for two sets of names.
- Digital Multi-Day Maximum/ Minimum Thermometer Data Sheet *(below)*
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimating the Current Temperature

1. Ask each class group for an estimation of the current temperature and write each one on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimation.

   Note: This is repeated from the last lesson, so that the students can gradually learn to make accurate estimations.

Explanation of our Data Collection System

1. Explain that two times each week a group will go to the digital thermometer to take data and then, if possible, upload the information onto the internet in order to make it available to everyone.
2. Here are the data that we will take from the thermometer
   a. **Maximum daily temperature for the air and for the soil**: The highest temperature recorded during a 24 hour period from noon to noon.
   b. **The minimum daily temperature for the air and for the soil**: The lowest temperature recorded during the day (24 hours from noon to noon)
3. Explain that each week the students will need to record the temperature data in their notebooks as well as on the school's GLOBE data sheet.
4. Then, they will return to class and place the data for that week on the class graph posted on the classroom wall. An example of the layout for this graph can be found at the end of this lesson.

   Note: Also, from time to time, it could be interesting to ask the students to calculate other statistics from the data to place on a second graph as a way to practice calculations, graphing, and statistical measurements:
   a. *Daily average temperature:* $T_{average} = (T_{max} + T_{min}) / 2$
   b. *Monthly (or weekly) average temperatures: the average maximum temperature and the average minimum temperature for the month (or week)*

$$Ex.\ T_{average} = (T_{max1}+T_{max2}+T_{max3}\ldots T_{max30})/30$$

Game: Place the Button on the Thermometer

1. Explain: At this time, we are going to review the digital thermometer with a game.
2. Draw the digital thermometer on the blackboard without labeling the buttons.
3. Ask a volunteer from each team to come to the blackboard, and cover their eyes with a bandana.
4. Give each one a piece of paper with the same name written on it, to which you have attached a piece of tape. Spin each blinded student.
5. Then each group has to verbally guide their teammate to the board and have them correctly place the button. The first team to correctly place the "button" gets a point for the group. Alternatively, for a quieter version, have each team go separately and time them. The group that does it the fastest wins the point.
6. Play for each button using different students each time.

Go Out to the Site

1. Once the game has finished, take the students outside to see the thermometer in its instrument shelter and to take data. Remember to take into account the time of day that you are taking measurements to ensure that you are placing the temperatures under the correct dates.
2. Return to the classroom and plot the temperatures on the class graph.
3. Set up a data collection system whereby a different group will come and help the teacher take thermometer data and also to plot the data on the class graph each time

Temperature Data Sheet

Study site name and location: ____________________ Month and Year: ________________

Time of data collection:

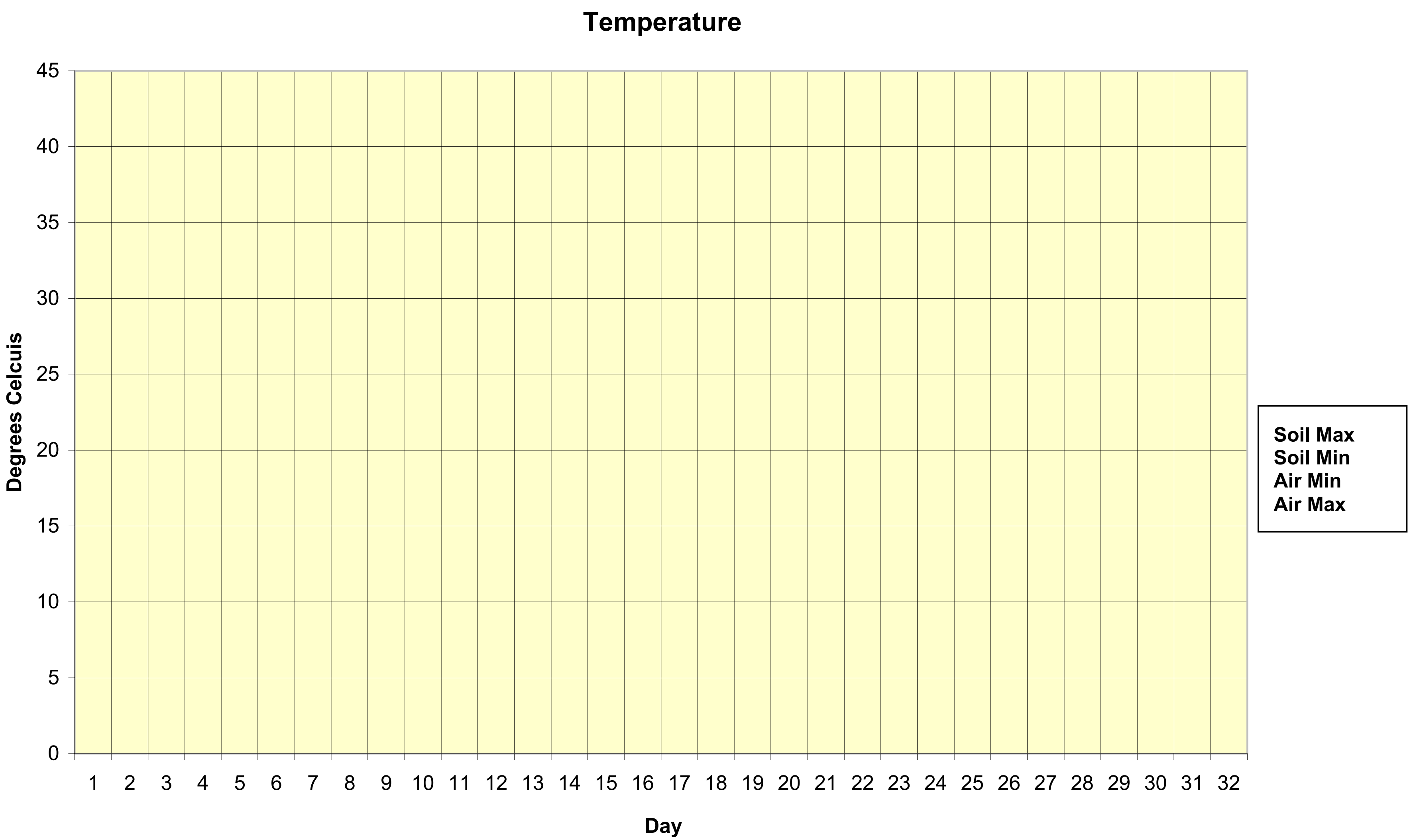
Local time: _______________________ Universal time: ____________________

Coordinates:

Altitude: ______________ Latitude: _________ Longitude: _________

Note: If you read your thermometer **after** the hour of initialization, D.1 is **today**.
If you read your thermometer **before** the hour of initialization, D.1 is **yesterday**.

	Air		Soil	
Day	**Maximum Temperature**	**Minimum Temperature**	**Maximum Temperature**	**Minimum Temperature**
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				


Temperature
Degrees Celcuis
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Day
Soil Max
Soil Min
Air Min
Air Max

Building a Liquid Thermometer and Explaining How it Works

GLOBE Temperature – Lesson 3a

<u>Note</u>: If this activity is too hard for the level of the students, you can build one thermometer together as a class demonstration.

<u>Note</u>: Elementary school classes should do only the first lesson as written. Higher levels can take data as explained at the end of this lesson and then continue on to do the graphing lesson.

Materials and Preparations:

- Yesterday's minimum and maximum temperatures
- Alcohol thermometers
- One narrow-necked bottle per group with a hole poked in the lid that is just large enough for a straw to be squeezed through *(Smaller bottles work well)*
- One empty and clear tube from a pen or a clear straw for each group
- One packet of drink mix, food coloring, or other method of coloring a bucket of water
- Some high quality modeling clay or a dough from the following recipe:

  ¾ cup flour and ¾ cup salt mixed with enough water to moisten the mixture without it becoming sticky (Near a ¼ cup). Knead well to improve elasticity and texture.

- A large cup or small container for each group that is large enough to hold the bottle
- A bucket of hot water (but not too hot)
- A bucket of cold (cool) water
- A bucket of water mixed with the drink mix or coloring
- Some cups to transfer water from the buckets to the students' containers
- A marker (if available) or a little tape to mark the starting level of the water on the tube
- Students' GLOBE notebooks
- A ruler for each group*
- A watch or clock*

**optional materials for more advanced students*

Lesson Plan:

Game: Estimating Yesterday's Temperature

1. Ask each class group for an estimation of the current temperature and write each one on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimation.

Explaining the Workings of a Thermometer

1. Review: Ask the students, “What is a thermometer?”
2. Draw an alcohol thermometer on the blackboard.
3. Describe the parts of the thermometer to the students:
    a. Sealed glass tube
    b. Passage through the glass tube
    c. Liquid reservoir
    d. Liquid (colored alcohol or sometimes mercury)
    e. Scale in ˚C running the length of the tube
4. Show the students a real thermometer and ask them how it functions but do not give any answers.
5. Explain that we will start to answer this question by building thermometers together.

Fabrication of a Thermometer

1. This experience will allow the students to see dilation and contraction in action through the fabrication of a thermometer.

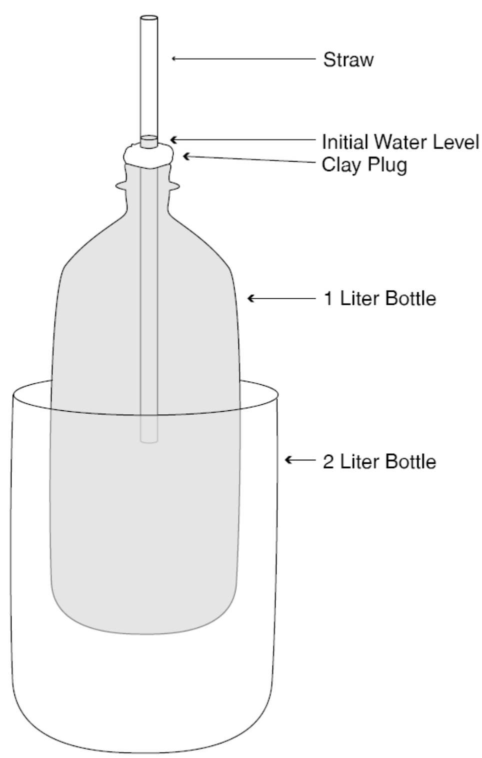


Figure AT-TH-6

2. Ask all of the groups to place their bottles and their empty pen tubes on their desks.
3. Give each group a piece of the clay and a container if the students did not bring their own.
4. Ask the students to wrap the clay around their tube, a little to one end.

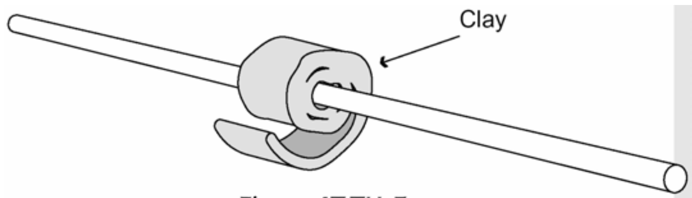


Figure AT-TH-5

5. Have the students fill their bottles with colored water right to the top.
6. Pass the straw or pen tube through the hole and seal it in place with the clay mixture.
7. Screw the cap onto the bottle. Check for leaks around the straw, wipe off any extra water, and add more clay as necessary.
8. If necessary, add colored water to the tube with a dropper (or squeezed from a wet cloth) to raise the level of the water to halfway up the tube. This way, the water has space to expand and contract.
9. If you have a marker, ask the students to mark the starting level of the water on the tube using a fine line. If you do not have a marker, use a piece of tape or another method.
10. Place the prepared bottle, which is now a simple thermometer, into the group's small bucket. Hold it at its neck so the colored water is not squeezed out of the bottle.

    Note: At this point higher level classes will want to pass to the section below entitled "For more advanced students" for the construction of data tables and the taking of quantitative data.

Making Qualitative Observations with the Thermometer

1. Add a little hot water to the outside container of each group. Ask the students to watch for a change as you add water to the other groups' containers.

    Note: Be careful not to add too much hot water right away as that can cause the colored water in the thermometer to overflow. The water will move around 40 mm if the water temperature is changed 25°C

2. If you do not see a large enough change, add a little more hot water to each groups' container.
3. Ask the students to describe what happened to the water in their thermometer when the water temperature was increased. Response: The water expanded and moved up the tube.
4. Ask the students to carefully lift out their thermometers from the water baths by their necks and without squeezing them. Have the students throw out the hot water in their containers.
5. Place the thermometer back into the empty container.
6. Now, using cold water, repeat steps 1 and 2.
7. Ask the students what happened with the cold water. Response: The water contracted and moved down the pen tube.

Explanation of What We've Seen *(revise as necessary depending on the level of the students)*

1. **The origin of the change in volume**: All matter is composed of atoms and molecules. If these molecules are cold, they contain a little bit of energy. Because of this, they cannot move very much so they sit close to one another without taking up much space. But, once heat is added to these molecules, they gain lots of energy and they start to

move a lot. At this moment, each molecule has need of lots of space in order to move and as they move apart, the volume of the matter expands also.

2. **Comprehension activity**: An analogy: Tell the students to pretend that they are cold molecules and pack them in very tightly into a corner of the classroom. Have them stand still and note how much space they are occupying. Then explain that now they gain a lot of energy and they should now start dancing wildly. After some time, have them stop and look at the much larger space they now occupy.

How a Thermometer Works:

1. The function of a thermometer is based on the dilation of a liquid (the change in the liquid's volume) that it contains. If the liquid is hot, it expands in the tube for the reasons above and we say that the temperature rises. If it is cold, the liquid contracts in the tube and we say that the temperature falls.
2. The principal temperature scale that we use on thermometers is degrees Celsius (˚C). It looks like a ruler on the thermometer's tube, but instead of measuring distance in centimeters or millimeters, it measures temperature.
    a. This scale is created by making zero degrees the temperature at which water freezes and one hundred degrees the temperature that water boils. Between these two points on a thermometer, the distance is divided in 100 equal parts thus creating the size of one degree. Knowing this distance allows for the continuation of the scale above and below 0 and 100°C.
3. Ask the students to give the temperature of the human body (37˚C)
4. Pass through the class with one or two thermometers and ask each student to read its value in silence and write their reading on a piece of paper.
5. Read the thermometer yourself and tell students the temperature.
6. With a scale drawn on the board help students who did not get the correct temperature to understand how to read a thermometer.
7. Pass back through the class with the thermometer for students who still have not understood.

For more advanced students at the middle or high school level

1. Have the students recopy the following data table into their notebooks so they can collect data in an organized fashion.

Movement of the Colored Water in the Tube

0 min	2 min	4 min	6 min	8 min	10 min	**Change the water**	12 min	14 min	16 min	18 min	20 min
						-----					

2. Have each group place their bottle in their bucket and add one cup of hot water to each one.

    <u>Note</u>: Be careful not to add too much hot water right away as that can cause the colored water in the thermometer to overflow. The water will move around 40 mm if the water temperature is changed 25°C.

3. If you do not see a large enough change, add a little more hot water to each groups' container. Ensure that each group receives the same amount of hot water.
4. Observe the dilation of water. Have to students measure the distance, in millimeters, that the water expands from its starting point in the tube, indicated by the marker line. Each group should take a measurement every two minutes for a total of ten minutes. Wait until all the groups are done before moving on.
5. Have the students remove their thermometers from the water baths by the necks of the bottle. Remind them not to squeeze their bottles.
6. Have the students dump out the hot water in their basin and replace it with cool water. Water that has been cooling in a clay pot (canari) will work well.
7. Observe the contraction of water. Measure once again the movement of the surface of the water from the original marked line. Tell the students to take a measurement every two minutes for ten minutes and to record the measurements on their data table. As the water level falls beneath the original mark, the students should record a negative number.
8. Once the students have finished taking data have them clean up their experiments and empty all their containers.
9. Collect the data sheets from each group or tell the students not to lose these data sheets between now and the next session.

Make a Graph and Explain the Thermometer Construction Activity

(For secondary students only)

GLOBE Temperature – Lesson 3b

Materials and Preparations:

- Alcohol thermometer
- The students' data from the last session
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimating the Current Temperature

1. Ask each class group for an estimation of the current temperature and write each one on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimation.

   Note: This is repeated so that the students can gradually learn to make more accurate estimations.

Calculating the Average & Making a Graph of the Data from the Experiment

1. Draw the following table on the board and ask each group to come up and report their data. Verify that all measurements made when the water was underneath the marked line carry with it a negative sign.

Class Data: The Movement of the Colored Water

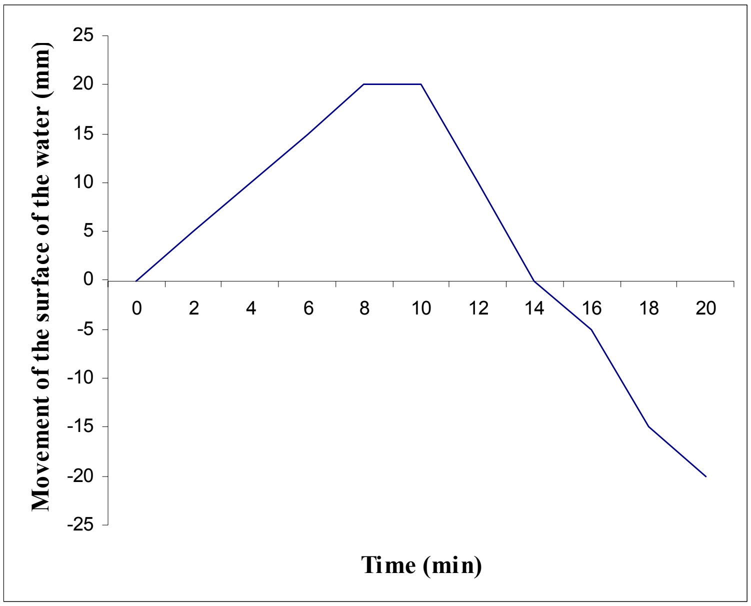
Group	0 minutes (mm)	2 minutes (mm)	4 minutes (mm)	6 minutes (mm)	8 minutes (mm)	10 minutes (mm)
1	0					
2	0					
3	0					
4	0					
Average :						

(continued)

Group	Changed the water	12 minutes (mm)	14 minutes (mm)	16 minutes (mm)	18 minutes (mm)	20 minutes (mm)
1	At					
2	This					
3	Point					
4						
Average :						

2. Assign each group a column and ask them to calculate the average for the numbers in that column and then to place that value in the data table.
3. Take the averages and put them on a class graph on the blackboard. The horizontal axis is the time in minutes and the vertical axis is the distance the water moved in millimeters. Make sure that the graph you draw can accept negative numbers for the Y-axis.
4. Ask the students to describe the line on the graph: What does this graph show you? Can you draw any conclusions from the shape of the line?

Example Graph of Possible Results



Creation of Possible Explanations

1. Tell the students to write a three sentence report in their notebooks of what they have seen and what they think happened in regards to the question: Why did the surface of the water advance and then retract?
2. Permit the students to share their explanations before continuing on to the explanation.

   Note: Do not dissuade or mock any student for their suggested reasons. Encourage each student's effort and their suggestions. When students try to think for themselves it makes their minds grow stronger. It is important for each student to think for himself in order to develop.

Explanation of What We've Seen

1. **The origin of the change in volume**: All matter is composed of atoms and molecules. If these molecules are cold, they contain a little bit of energy. Because of this, they cannot move very much so they sit close to one another without taking up much space. But, once heat is added to these molecules, they gain lots of energy and they start to move a lot. At this moment, each molecule has need of lots of space in order to move and as they move apart, the volume of the matter expands also.

2. **Comprehension activity**: An analogy: Tell the students to pretend that they are cold molecules and pack them in very tightly into a corner of the classroom. Have them stand still and note how much space they are occupying. Then explain that now they gain a lot of energy and they should now start dancing wildly. After some time, have them stop and look at the much larger space they now occupy.

How a Thermometer Works:

1. The function of a thermometer is based on the dilation of a liquid (the change in the liquid's volume) that it contains. If the liquid is not, it expands in the tube for the reasons above and we say that the temperature rises. If it is cold, the liquid contracts in the tube and we way that the temperature falls.
2. The temperature scale on a thermometer: The principal temperature scale that we use is based on degrees Celsius (˚C)
    - This scale is created by making zero degrees the temperature at which water freezes and one hundred degrees the temperature that water boils. Between these two points on a thermometer, the distance is divided in 100 equal parts thus creating the size of one degree allowing for the continuation of the scale outside of this range.
3. Ask the students to give the temperature of the human body (37˚C)
4. Pass through the class with one or two thermometers and ask each student to read its value in silence and write their reading on a piece of paper.
5. Read the thermometer yourself and tell students the temperature.
6. With a scale drawn on the board help students who did not get the correct temperature to understand how to read a thermometer.
7. Pass back through the class with the thermometer for students who still have not understood.

Studying the Instrument Shelter

GLOBE Temperature – Lesson 4

Materials and Preparations:

- A simple instrument shelter made out of white cardboard
- A simple instrument shelter the same as the white one but painted or colored black instead of white
- Two alcohol thermometers
- Students' GLOBE notebooks

Lesson Plan:

Overview of How to Carry Out a Scientific Experiment

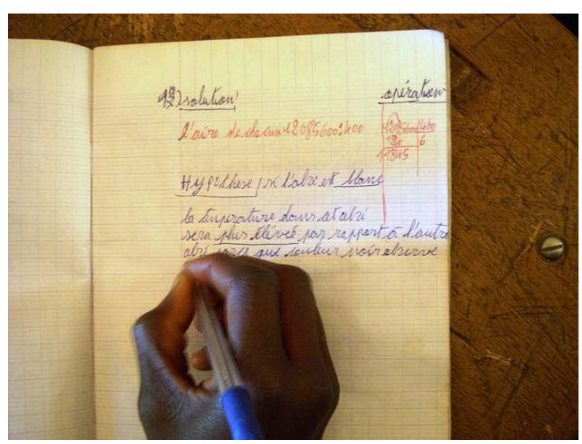
1. Explain that all scientists use the same process when they are doing an experiment.
2. Generally, this process includes the following steps:
    a. **Problem**: A statement of the question that needs to be answered
    b. **Hypothesis**: A prediction of the result of the experiment
    c. **Procedure**: An explanation of the process, by steps, of the experiment so other scientists can repeat the experiment exactly if they want to.
    d. **Data** (and analysis of data): A scientist will do the experiment several times and take data each time, recording it in data tables in this section
    e. **Conclusion**: Examine the data and decide if the hypothesis was supported ("true") or not supported ("false") and then create another problem that builds on this experiment.
3. Explain that we will follow this process in order to understand the function of our instrument shelter's color.

Describe the Problem

(Each group or student works on their own paper.)

1. Tell the students to copy the following **Problem** into their notebooks:

    Problem: Does the color of our instrument shelter have an impact on the temperature read by the thermometer inside?



Create a Hypothesis

1. Have each student create and write a **Hypothesis**, a prediction of the answer to the Problem (in other words, of the results of the experiment).

Note: The teacher must not give the students any answer whatsoever. Also, he must insist that the hypotheses are the students' own predictions and that there is not a right answer at this time.

The teacher, without giving an answer, can guide the students in explaining that their hypotheses can follow the following form:

Hypothesis: If the instrument shelter is _______________ (white / black), the temperature in this shelter will be ________________ (higher / lower) in comparison to the temperature in the other shelter because ______________________________.

2. Ask several students to share their hypotheses with the class.

   Note: Remember that all hypotheses are valid and should all receive encouragements. Do not judge any response.

Explanation of the Procedure

1. The next step is to describe the **Procedure**. Read the following procedure out loud to the students:
   - We have constructed two instrument shelters out of cardboard, identical other than their color – one is black and the other is white.
   - We have hung a calibration thermometer in each shelter, making sure the thermometers are not touching any part of the shelter.
   - We will take the temperature from the thermometer in each instrument shelter at the beginning, while they are sitting together in the classroom out of the sun. This initial reading will give us something to compare our final results to.
   - Then, we will place the two shelters outside in the sun, wait 15 minutes, and take the temperature of each shelter again.

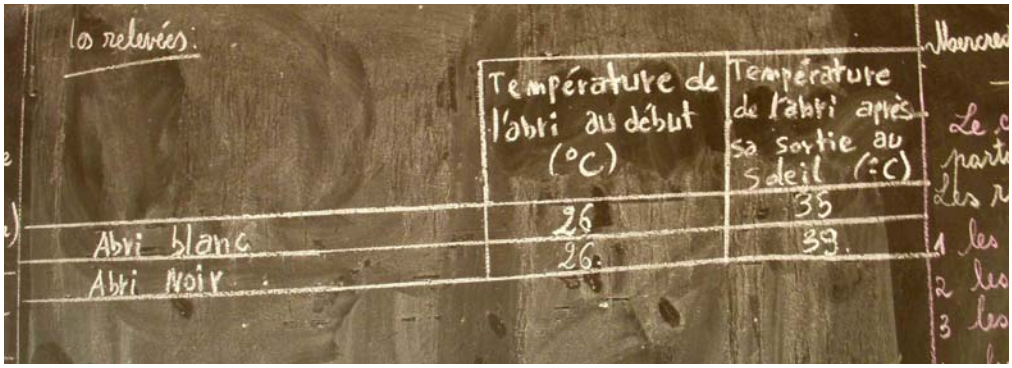
Do the Experiment and Take Data

1. Follow the steps above to do the experiment – take the initial temperature, put the instrument shelters in the sun for 15 minutes, then take the temperatures again.
2. While waiting the 15 minutes, write the following data table on the board and have the students copy it in their notebooks:

Data Table: Instrument Shelter Temperatures

	Temperature of the instrument shelter at the start (°C)	Temperature of the instrument shelter after being in the sun (°C)
White instrument shelter		
Black instrument shelter		

3. If the fifteen minutes is not yet up, play the temperature estimation game, guessing either the current temperature or the maximum and minimum temperatures from yesterday. Alternately, play the GLOBE countries of the world game, or practice making hypotheses about other various problems.



4. After the 15 minutes are over and the temperatures have been recorded, look at the data together and perform a **<u>Data Analysis</u>**.
5. Ask the students to describe what happened. In the end, the students should explain that both of the shelters had the same temperature when they were inside, but once they were in the sun the temperature in the black shelter rose much higher than the temperature in the white shelter.
6. So, the black shelter is not reporting an accurate temperature as it has been overheated by the sun.

Write a Conclusion

1. Ask each student or group to write a small conclusion at the end of their experiment explaining what happened and if their own hypothesis was supported or not supported.

Extension of the effects of color

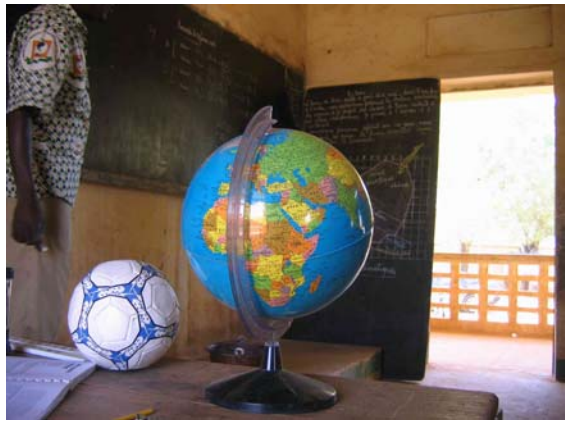
1. Explain that many things in nature and many things that people build are a certain color based on how hot the color gets. Present the following examples:
    a. Some towns in hot climates paint all of their buildings white in order to help reflect the sunlight and keep them cool.
    b. Many people only wear light-colored clothing on hot days to help them avoid overheating.
    c. Large cities, such as Niamey are hotter than the surrounding villages because all of the dark buildings and asphalt absorb sunlight and heat up the city as a whole.
    d. Some animals, such as certain lizards can change the color of their skin in order to absorb or reflect sunlight and help warm them up or keep them cool.

More Practice

1. If you have the time, practice making hypotheses on various problems or do a second experiment with them on two white shelters, identical other than one has air vents and the other does not. This experiment could be used as a second lesson, where the students have more control over the experiment now that they have seen an example.

Connecting the Temperature to the Environment

GLOBE Temperature – Lesson 5



Materials and Preparations:

- ❑ Alcohol thermometer
- ❑ Football (soccer ball) <u>or</u> a globe
- ❑ Blank white sheet of paper
- ❑ Flashlight
- ❑ Students' GLOBE notebooks

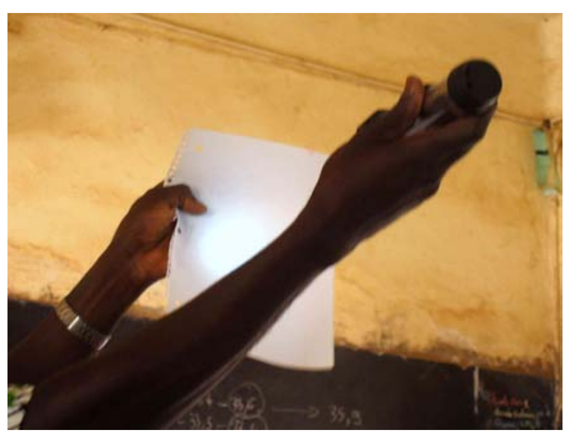
Lesson Plan:

Game: Estimating the Current Temperature or the Min/Max from Yesterday

1. Ask each class group for an estimate of either the current temperature or the minimum and maximum temperature from yesterday, and write their estimates on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimate.

Exploring the Causes of Variations in the Daily Temperature

1. **<u>Changes in daily temperatures</u>**: Why is there a temperature difference between the air temperature at 9:00 a.m. and the temperature at noon? (East-West movement of the sun)
   a. As the Earth turns on its axis, it presents different faces of itself to the sun. The face that sits directly below the sun gets hit by the most sunlight and the hotter it becomes (near noon) whereas the areas that are not underneath the sun receive less light and are not heated as much (in the early morning and late afternoon).
   b. To show this effect to the students, shine a flashlight directly onto a piece of paper so the rays of light from the flashlight are perpendicular to the page and the flashlight beam makes a tight and perfect circle on the paper. Tell the students to note how bright the light is at this point and that the light forms a circle on the paper. Explain that this represents and area directly beneath the sun. Then, tilt the paper until the light approaches from an angle that is far from perpendicular. The circle of light will become dimmer and oval-shaped. The shape is now less bright because the rays of light have been spread over a larger area than they were before, representing a location not directly underneath the sun like here in the early morning.



c. Now demonstrate the same thing on a rounded surface to model this effect on the Earth. Mark the surface of the football with a small X or point to a specific place on the globe and explain that the mark represents our location on the surface of the Earth. Then, shine a flashlight on the surface of the ball and rotate it. Show the students that as the ball turns, the X moves in and out of the bright part right under the flashlight to the dimmer edges of the lit area to the unlit backside. This is exactly what our school/town/city does in relation to the sun as the Earth spins during the day.

2. **Monthly or seasonal variations**: Why is there a difference between the temperature at noon in January and the temperature at noon in April? (North-South movement of the sun)
   a. The earth is tilted on its axis. (Tilt the ball or globe to demonstrate this.) This tilt also changes the intensity of sunlight that hits a specific place on the globe but this time instead of daily changes it causes monthly or seasonal changes. (For middle and high school students: Latitudinal changes as opposed to Longitudinal changes)
   b. Repeat the same demonstrations with the ball (and/or the paper) but instead of rotating the ball change its tilt in relation to the sun. Explain that the Earth is tilted and that changes the angle at which the sun hits its surface as the Earth rotates around the sun. So, when the Earth is tilted one way, the flashlight (the sun) is hitting Niger directly at a 90˚ angle in a North-South sense, it creates the hot season here (ex. Niger in March and April). When the light is not directly over Niger in a North-South sense, it is the cold season (ex. Niger in November and December).

3. **Variations across the world**: Why is there a difference between the temperatures at noon in April here as compared to the same time in Norway, Senegal, or Casablanca? These variations are also due to the angle at which the sunlight hits the earth.
   a. **Exercise**: Have the students identify the deserts of the world on a globe or map. The majority of them are not far from the equator. Part of the reason for this is that the sun is beating down directly on these regions for a large part of the year.

4. **Other sources of temperature variation**
   a. **The proximity of water**: Large bodies of water keep the temperature of the air around them steadier as water can absorb and release lots of heat. So, the water absorbs heat during the day, keeping the air cooler, and releases heat at night, keeping the air warmer.
   b. **Altitude**: The higher up in elevation that a place is, the colder it will be. Each 1000 m gain in elevation equals a temperature drop of around 6.5˚C.

The Impact of Temperature on the Environment

Note: This may need to be simplified or omitted depending on the level of your students.

1. Because temperature has a huge impact on the lives of living things, plants and animals are well adapted to life in an area with regular temperature ranges.

- **Example**: Near the North Pole, where it is very cold, polar bears have special fur that guides sunlight to their skin and warms up the bear. But because of this, they are unable to withstand a location with a lot of sun and high temperatures as they will overheat.

- **Example**: Pine trees have very small leaves that are covered in wax. Leaves like this protect the tree against freezing in the cold weather. However, they are unable to grow in hot climates because of this leaf shape.

- **Example**: Cactus (desert plants) have a thick skin and they only exchange gasses during the night in order to avoid water loss during the hot days. But, they are unable to adapt to weak sunlight and do not grow near the poles.

- **Example**: Crocodiles are well adapted to warm waters and warm regions using the heat of the water and the air to heat and run their bodies. However, they die in cold water as they are unable to heat their bodies themselves.

Note: Photo credit: Polar bear from the USGS, Alligator from NASA, Cactus from Free Nature Pictures, pine from the USDA NRCS, and pine needles from the NPS.

2. Once the temperature in a region changes, even by a few degrees, not all of the plants and animals there can survive the change and some species will go extinct. **Extinct** means to permanently disappear from the Earth.

Global Warming (Climate Change)

GLOBE Temperature – Lesson 6

Materials and Preparations:

- Watch
- Students' GLOBE notebooks

Lesson Plan:

Review of the Causes of Temperature Variation

1. Ask the students: "From what we saw last time, what are some factors that influence changes in air temperature?"
   - The students should answer: the angle of the sun over the course of the day, the angle of the sun due to the tilting of the Earth, the proximity of a large body of water, and the altitude of a locality.

Explaining the Science of Global Warming

1. Say that there is another force that is changing global air temperatures, and that it comes from human activity. It is global warming.
   a. Definition: Global warming is just what it sounds like it is – **Global warming** is the steady increase in the average air temperature of the Earth.

2. **Explanation**: Say that global warming comes from the release of "**greenhouse gasses**" (especially carbon dioxide among other harmful gasses) in the atmosphere by humans. These greenhouse gasses keep heat in the atmosphere and do not permit them to escape. These gasses serve as a blanket (or a coat) for the Earth. They reflect heat back towards the Earth.

3. **Analogy**: Say: "Imagine that you are in a car during the afternoon and the sun is burning hot. All of the windows and the doors are closed. What will happen to the temperature inside the car? "
   - The students should answer that the temperature will increase.

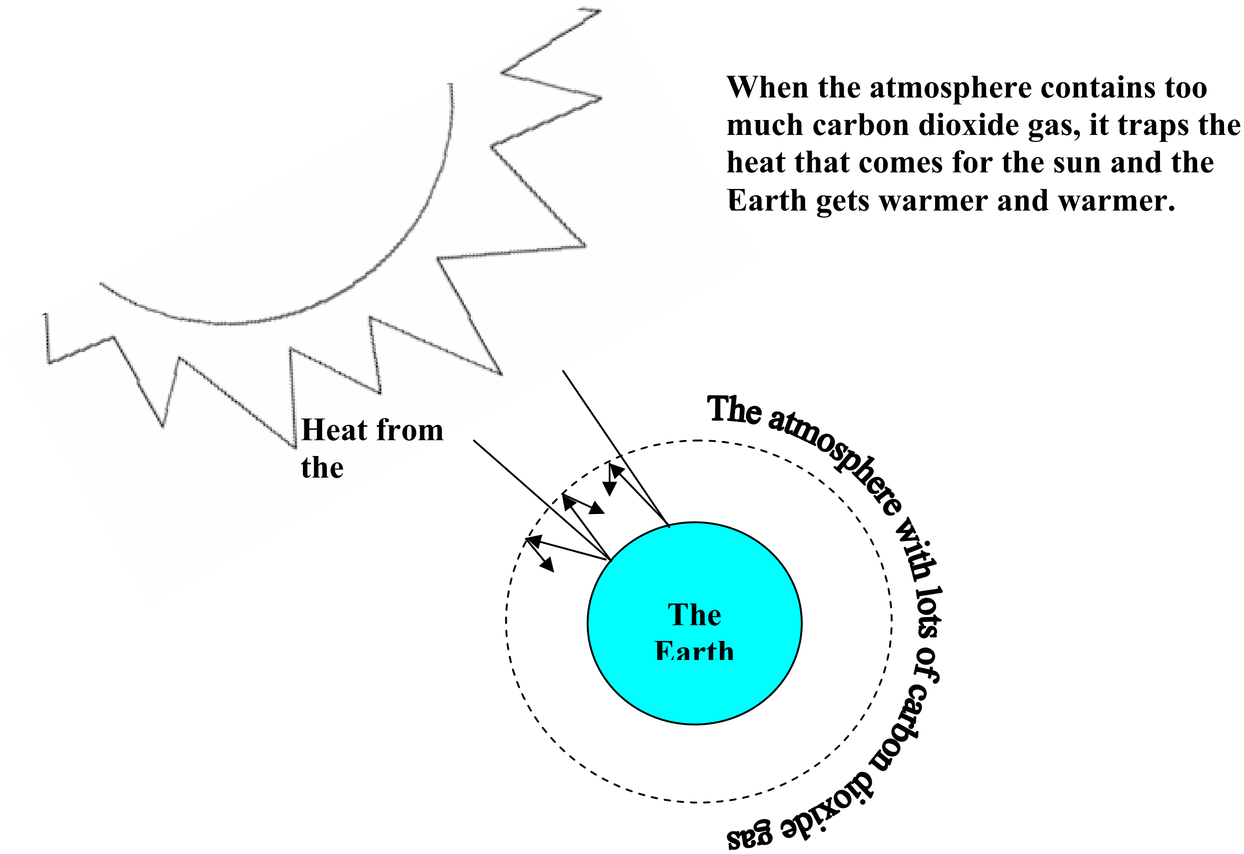
   "Will it be hotter than outside?"
   - Yes – much hotter.

   "Why?"
   - Because the heat is kept inside the vehicle by the closed windows.

   Explain that Global Warming does the same thing – the gasses do what the car windows do and keep lots of heat inside the atmosphere.

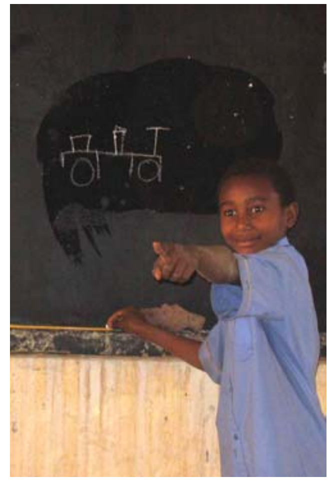
4. **Draw** the following visual explanatory drawing on the blackboard and ask the students to copy it into their notebooks at the same time:

Simple Sketch to Explain Global Warming



Game: Explaining the Sources of Carbon Dioxide

1. Ask: What do you think are some sources of carbon dioxide?
2. After they have suggested some sources, tell them that we are going to play a game to reveal the sources.
3. How to play the game:
   a. Place the students in two to four groups and then explain the rules of the game.
   b. The first group will choose a representative to come to the blackboard.
   c. The teacher shows the student at the board one of the following phrases, but he should not show or tell the rest of the class the word.
   d. The representative at the board has one minute *(or less if this is too easy for the students)* to draw images on the blackboard that will let his teammates guess the phrase (the source of carbon dioxide). The person at the board can **only** draw – he may not talk or write any words on the blackboard. If he does either, he loses the point for the team and it becomes the next team's turn.
   e. At the same time, the rest of the team should try to guess the phrase. If someone on the team thinks they know the answer, he should call it out so that the student at the board can signal "yes" or "no" (without speaking).
   f. If the group guesses the phrase, the group earns a point and the teacher writes the phrase on the blackboard to start a list of sources on the blackboard.
   g. Have each team come to the blackboard in turn to draw until the entire list has been played.
   h. The team that guessed the most phrases correctly is the winner.



4. Here are the Global Warming sources to use during the game:
    - Burning wood
    - Charcoal
    - Burning trash
    - Gas stoves
    - Generators/motors
    - Cars
    - Motorbikes
    - Trucks
    - Large factories
    - Electricity (power plant)

5. After the game, review all of the sources of carbon dioxide that are now in a list on the blackboard. Explain that it is in burning gasoline, gas, petrol, kerosene, wood, diesel, plastics, trash, charcoal, etc, that we produce carbon dioxide and the other gasses of global warming.

Why Are There More Harmful Gasses in the Atmosphere Now Than There Were 100 Years Ago?

1. This is because we have more vehicles, more generators, more fires, and more humans than any other time in history. Also, we have fewer places that can store these extra gasses, such as trees.

What are the Consequences of a Rise in Temperatures due to Global Warming?

1. Once the temperature in a region changes, even by a few degrees, not all of the plants and animals there can survive the change and some species will go extinct. **Extinct** means to permanently disappear from the earth.
2. Global warming will also increase the length and severity of droughts and flooding, especially in countries that are already arid like Niger. This will lead to a loss of crops and then famines.
3. There will also be an effect on the oceans. If the global average air temperature of the Earth rises only 2°C, all the ice at the poles of the Earth will melt. This process will start with the ice on Greenland. This ice alone will raise the level of the world's oceans by seven meters! This situation will create huge consequences, even in landlocked countries like Niger – for as the water level rises, much of Nigeria and other costal areas will be underwater. This rise will create many environmental refugees that will be forced to leave their villages that are covered by water and move inland. Niger could feel pressure as ports are flooded making it difficult to deliver goods and environmental refugees move into the country looking for dry land.

What Can We Do to Combat the Situation?

1. Plant trees! Niger is already doing some of this and has more trees now than it did thirty years ago, but more needs to be done.
2. Reduce our personal release of greenhouse gasses.
3. Try to persuade the World's governments to work for the future of humanity and reduce the amounts of greenhouse gasses that they release.

This is truly a huge problem that we must work to conquer together and soon.

Studying Graphs

GLOBE Charts and Graphs – Lesson 1

Materials and Preparations:

- Blackboard meter stick
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimating the Current Temperature (or the Min/Max from Yesterday)

1. Ask each class group for an estimate of either the current temperature or the minimum and maximum temperature from yesterday, and write their estimates on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimate.

   Note: You could alternately play the game "GLOBE Countries of the World."

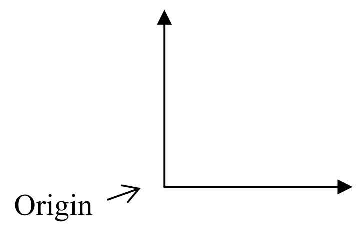
Importance of Graphs

1. Ask the students, "What is a graph? Why do we use graphs? Why are they important?
2. After the students have shared their ideas, explain that a graph is a visual representation of two sets of related numbers. That means two sets of data that are connected in some way such as the number of kilometers that one has traveled over the course of several hours. The time is one set of data and the number of kilometers is the other set.
3. A graph lets us clearly see the relationship and any changes that occur between the two sets of numbers.
4. The changes that happen across sets of data are called **trends**.
5. Line graphs are the most common type of graph. A line graph is often used to show change over time and we will look at some examples of line graphs today.

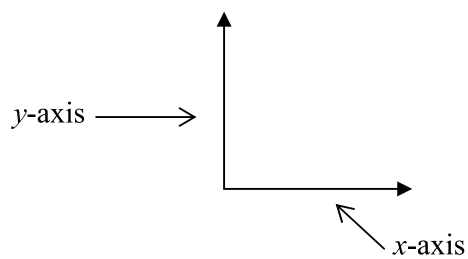
How to Construct a Line Graph

Note: Indeed, while students at the primary school level do not need to learn all of the technical terms found below, they can still learn to construct graphs accurately with the use of the following explanation and vocabulary that places these ideas at their level. Elementary school students can still learn how to draw great graphs themselves with an hour or so of good instruction.

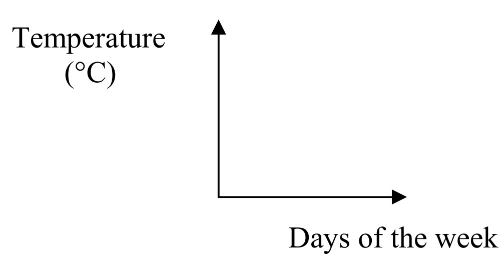
1. The construction of a line graph starts with the drawing of two lines at a right angle to each other. These two lines emerge from the same point called the **origin**.
   a. Draw the following on the blackboard:



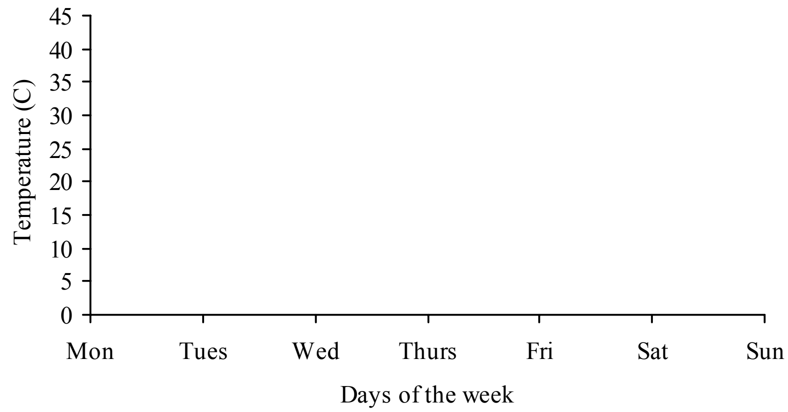
2. Each line itself is called an **axis**. The horizontal line is called the **horizontal axis** or the ***x*-axis**. The vertical line is called the **vertical axis** or the ***y*-axis**.



3. Each axis has a scale that corresponds with one of the sets of numbers that we are looking at.
4. Each set of data is called a **variable**. Almost always, if we have a variable that involves time, it will go on the x-axis and the other variable will go on the y-axis.
    a. This is because one variable always depends on the other variable in a graph. The variable that is dependant goes on the y-axis and the variable that is independent goes on the x-axis. As time is independent, meaning that it continues on without being influenced by other things, it is almost always placed on the x-axis.
    b. Example: Temperature in degrees Celsius and Days of the week. Because Days of the week is a function of time, its scale will go on the x-axis and the Temperature, therefore, will be placed on the y-axis.

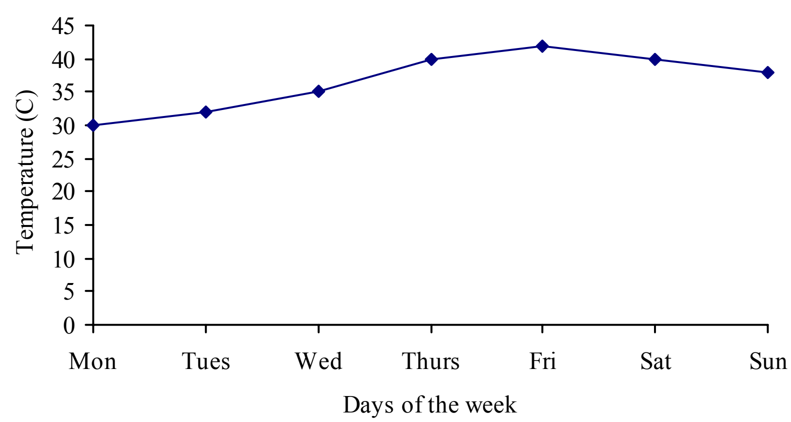


c. Along each axis, is a **scale** (like a ruler) that matches its label. For example:



d. Then, data points are added at points that match days of the week with the temperature for that day.

Day of the week	Temperature (°C)
Monday	30
Tuesday	32
Wednesday	35
Thursday	40
Friday	42
Saturday	40
Sunday	38



e. Let's practice what we have learned with an example concerning the number of wild giraffes living in Niger.

Example 1: Giraffes in Niger

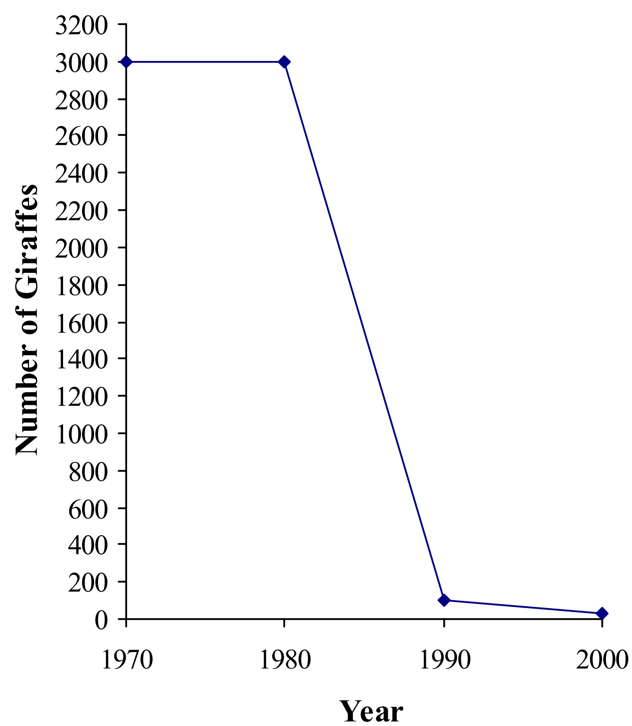
1. Ask a student to come to the blackboard and make a graph using the following data:

Year	Number of Giraffes
1970	3000
1980	3000
1990	100
2000	30

   a. Instead of doing the work for the student, give the student hints when they get stuck. The hints that they will most likely need here are that time (in this case the Year) goes on the *x*-axis and they will need help in choosing an appropriate scale for each axis that fits those they have drawn.

   <u>Note</u>: Most students have difficulty choosing an appropriate scale and the appropriate variable to place on each axis. This trouble comes from teachers that give to the students the completed axes every time they make a graph in class. In the GLOBE sessions, allow your students to struggle with setting up the graph's axes themselves, giving only a little bit of help once they become stuck. Remember students need to do it themselves in order to develop their brains and to be able to do a skill themselves on an exam.

2. The graph that the student constructs, should look similar to this one:



3. Ask the students to describe the graph by using words such as: ascending or descending, steep or gentle…
4. Looking at the graph, ask the students to propose answers to the following question: What are the possible causes for this drop in the population?
    - Hunting, poaching, loss of habitat (bush land), drought, illness…
5. Ask the students: Can you make a prediction for 2020?
6. Now add that in 2007, the population had climbed back up to 150 animals and there were lots of babies coming as well. Put this last data point on the graph.
7. Ask: What are possible reasons for this climb in the population?
    - A fight against poaching, the establishment of a society of guides from the surrounding villages by the government so the villagers now see the animals as a source of revenue through tourism.
8. Ask: "Can you make a second prediction for 2020?"

Example 2: Percentage of the Population Living with HIV/AIDS in Sub-Saharan Africa

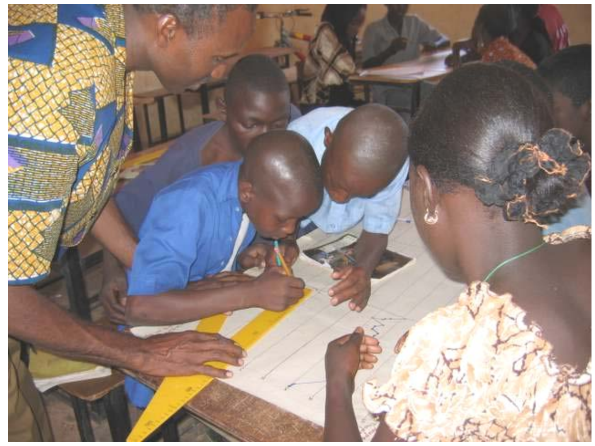
1. Ask a few students to come to the blackboard and construct a graph from the following data (data from the UN Report on the global AIDS epidemic)
    ‘

Year	Percentage of the population living with AIDS
1980	0.5
1985	0.5
1990	3.0
1995	5.0
2000	6.5
2005	6.1

2. Ask the students to describe the graph.
3. Ask: What are some reasons for the large increase in the numbers of infected people? (Non-protected sexual acts, infidelity, lack of medical care, lack of a medicine that can cure AIDS…)
4. Ask: Can you make a prediction for 2010? For 2020?
5. The percentage of people with HIV/AIDS living in Niger is near 1.1%. Where is Niger in relation to the average for sub-Saharan Africa? What will happen if the citizens of Niger do not protect themselves against HIV and other sexually transmitted diseases?

Graphing (cont'd)

GLOBE Charts and Graphs – Lesson 2



Materials and Preparations:

- Thermometer
- Tape measure or meter stick
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimating the Current Temperature (or the Min/Max from Yesterday)

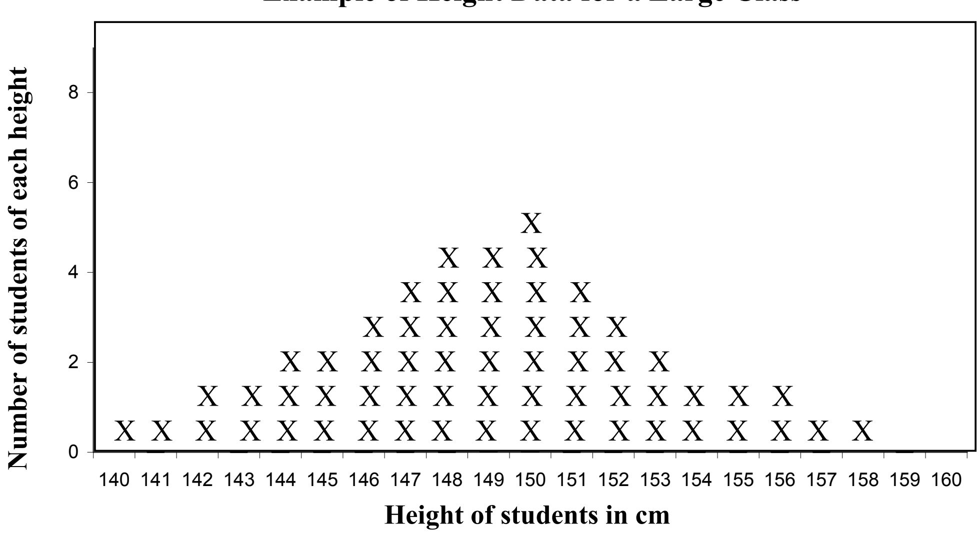
1. Ask each class group for an estimate of either the current temperature or the minimum and maximum temperature from yesterday, and write their estimates on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimate.

Example 3: Histograms

<u>Note</u>: Lower levels may want to skip this explanation and pass straight to the individual practice section.

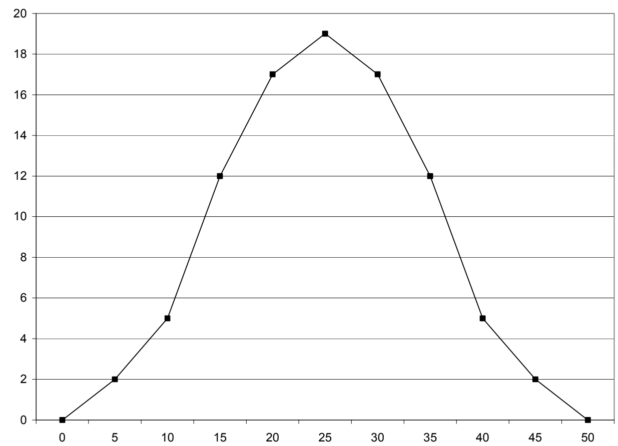
1. Tell the students that we are going to look at another kind of graph, called a **<u>histogram</u>**.
2. Have the students construct the axes of a graph on the blackboard with the horizontal axis in centimeters and the vertical axis in number of students by height. This is also a great time to review independent and dependent variables.
3. Measure the height of each student in the class. After each measurement, tell the student to place themselves on the graph with a cross. If a cross is already placed on a number for height, place the next cross for the same height on top of the first.

Example of Height Data for a Large Class



4. If the class is large enough, the students will see that the crosses form the shape of a bell. These **bell curves** are everywhere in nature – the mass of each individual of a species of mammal, the number of the children in a family, the daily incomes for the families of Niamey…

Example of a Bell Curve



5. **Explaining histograms**: This kind of graph is a called a **histogram**, and it is a good method to see the maximum, minimum, mean, median, and the amounts of something across a range. You can also use it to show changes over time. If you make a histogram now and then to do another one later and compare the two, you can see if the curve has shifted to the right or to the left, if the curve has become tighter or more flattened, etc. This information helps scientists. For example, they can see the changes in a population of animals, the grades of a class over several years, or the height of child during his development as compared to all other children.
6. Situations where the curve is not shaped like a bell, or situations where the curve changes over time are interesting to scientists and they will want to study it to know why.

   Note: In the classes of CM2 to 5ème, you might see that the girls and the boys form two separate bell curves. This is because the majority of girls reaches puberty well before the boys and is thus much taller as a whole.

7. Find the tallest students in the class, the shortest, the average, the median, and any irregularities in the graph.

   Note: If the size of your class is less than twenty or thirty people, it would be better to use the number of children in the immediate family (same mother) instead of heights to produce a good curve.

Individual Practice in the Construction of a Graph

1. Ask each student to make a graph of the following data:

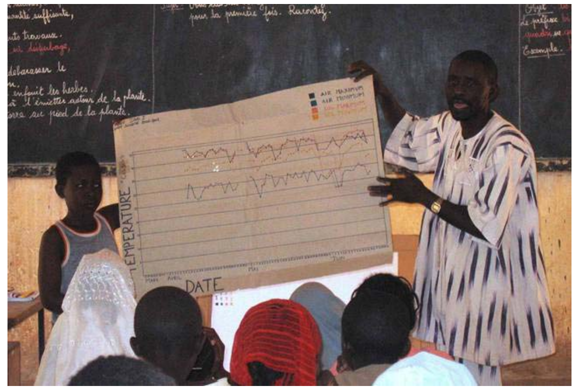
Average Rainfall at Niamey's International Airport 2000-2005

Month	Mm of precipitation during the month
1 (January)	0
2 (February)	0
3	0.1
4	7
5	16
6	102
7	149
8	158
9	94
10	12
11	0
12	0

2. Walk around the room and check the work of each student, and then ask one student from each group to recopy their graph onto the blackboard for the other students to judge which is most correct.
3. Ask students the name of this form of graph.
4. Ask: What would be the consequences if this curve were to flatten? Narrow?
5. Locate the seasons of the graph. Is there a correlation between the rain and the seasons? What is it?
6. Is there a connection between the rain and the flowering of the mango trees? The grasses? The millet?
7. Why do mango trees flower before the rains arrive while millet and other grasses flower after the start of the rainy season?
    - Response: The mango has enough water to flower during the dry season as it has deep roots and can therefore flower early to give its seeds enough time to establish themselves as new plants during the rainy season. Millet on the other hand, does not have access to water during the dry season and it must wait for the rain so it can grow before it flowers.
8. Ask the students any other interesting questions that you think of and then tell the students that we will continue this work together during the next session.

More Practice with Graphs

GLOBE Charts and Graphs – Lesson 3



Materials / Preparations:

- Thermometer
- Daily temperature graphs that are up to date *(if you are taking data)*
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimating the Current Temperature (or the Min/Max from Yesterday)

1. Ask each class group for an estimate of either the current temperature or the minimum and maximum temperature from yesterday, and write their estimates on the blackboard. Ask several students to read the alcohol thermometer and see which group made the best estimate.

Verify that the Temperature Graphs are Up-to-date

1. If not, tell the students to update them.

Temperature Data *(skip this section if you are not taking temperature data)*

1. Hang the temperature graphs for your school on the board.
2. Ask students to describe each of the four lines on the graph and explain what they represent.
3. Start with a comparison between the air and soil maximums, and then do the same thing for the minimums. Why are the soil temperatures more stable than the air temperatures?
    - Response for secondary students: Since the air doesn't have many molecules (it lacks mass) it is really susceptible to changes of the sun's position. On the other hand, soil, with its large mass, can resist some degree of change.
    - Response for elementary students: The sun heats the air faster than it heats the earth because the air is very light and the earth is very heavy and solid.
    - Analogy: A big pot of water has more mass than a small pot of water and so the big pot takes longer to heat because it needs more energy put into it in order to boil.
    - So, if you take the soil and air temperature each hour during one day, you will note that the changes of the soil temperature are not as dramatic as those of the air. Also, you will notice soil temperatures lag behind the air temperatures.
4. If you have been calculating daily averages, ask the students, "Can you note the gradual changes in the curve of daily average through a few months? What explains these changes?"
5. If you have been calculating monthly or weekly averages, ask the students, "Can you see any gradual changes in the monthly averages over several months? What explains these changes?"

Practice Constructing Axes

1. Ask the students to set up the axes of graphs for the following data sets, or other sets of numbers that you generate yourself. Since the emphasis is on the scale of the axes, the students are not necessarily obliged to plot all of the numbers if they have correctly set up the graphs.

Time (sec.)	**Volume of water (ml)**
0	0
5	6
10	13
15	25
20	37
25	42

Distance crossed (km)	**Animals seen**
0	0
3	15
5	30
9	47
14	60
20	75

Times (hours)	**Number of people at the baptism**
5:00	5
6:00	15
7:00	90
8:00	50
9:00	25
10:00	12
11:00	5

ml of water	**Amoebas present**
1	3
5	7
10	15
15	19
20	28
25	37

Introduction to Aerosols

GLOBE Aerosols and Clouds – Lesson 1

Materials / Preparation:

- Thermometer
- Hygrometer *(optional)*
- Relative Humidity Data Collection Sheet *(below)*
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimate the Actual Temperature

1. Ask the different groups their estimates of the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group had the closest guess.
2. Explain the importance of making good estimates.
3. If you haven't already done so in a past lesson, do some other estimations as a competition between groups. For example, have each group estimate the height of various objects in the class, then measure with the ruler to see which group came closest. They could also estimate the distance between objects, the exact time, etc.

Introduction to Aerosols

1. **Definition**: **Aerosols** are small liquid or solid particles suspended in the air – for example, water, toxic materials, dust, smoke, etc.
2. **Importance of aerosols**: Aerosols influence the weather and the climate because they block, reflect, or otherwise affect rays of sunlight. The more aerosols are present in the air, the hazier the sky.
3. **Quantity in the atmosphere**: Aerosols vary according to the seasons but in general there are many more aerosols now than there have been in the past two centuries. This change is due to human activities.
4. **Measure the intensity of aerosols**: One can measure the intensity of aerosols with the aid of a photometer.
5. **Why is it important to study aerosols**? Scientists study aerosols so that they can understand how the concentrations of aerosols change with the seasons and answer questions such as:
    a. What are aerosols' effects on the weather and the climate?
    b. How does the smoke from huge forest fires affect the sunlight that hits the surface of the earth?
    c. What is the relationship between atmospheric pollution and aerosols?
    d. What is the relationship between big industrial complexes and aerosols?
    e. What is the relationship between aerosols and global warming?

Water: A Very Important Aerosol

1. Definition: **Humidity** is the quantity of water vapor present in a body of air.
2. Definition: **Relative humidity** is the percentage of water vapor in the air compared to the quantity of water that the air can hold when it is saturated. (Saturated = full of water.)

$$\text{Relative Humidity} = \frac{\text{Quantity of water in the air}}{\text{Quantity of water the air can contain}}$$

3. **Analogy**: The air is like a sponge. It can absorb a fixed quantity of water. If the sponge drips water when taken out into a bucket of water, it is saturated and cannot hold any more water. If you squeeze it out, it still contains a little water but it is no longer saturated. The air is the same way. It can be saturated and unable to hold any more water or it can hold a little bit with room for more. You can calculate, then, the relative humidity of a sponge like you can for the air.
4. We measure the relative humidity with a **hygrometer**.

Introduction to the Hygrometer *(If you don't have one, skip this part and continue directly to Clouds)*

1. Image of a Hygrometer

2. Steps to Use a Hygrometer
    a. Turn on the hygrometer by pushing the red button on the back.
    b. Place the hygrometer in the instrument shelter (unless it is very wet out) preferably within one hour of solar noon. But if you are taking measurements from the photometer, you can measure both at the same time after mid-morning. In cases where the rain is imminent, simply write "100% because of the rain" on your Relative Humidity Data Sheet (below).
    c. After waiting thirty minutes, read the relative humidity and note which instrument was used.
    d. Read the current temperature record it on the data sheet.
    e. Turn off the hygrometer, carry it back into class and place it back in its dry storage container. DO NOT LEAVE the hygrometer in the instrument shelter overnight.
3. Maintenance:
    a. Storage of the hygrometer: Note that the hygrometer must be kept in a sealed and dry container.
    b. The container should have some grains of rice placed in it along with the hygrometer to absorb any moisture that is in the container and could damage the instrument. Change the rice from time to time.
    c. If the instrument is not used for a week or more, it is best to remove the batteries to protect the unit against the leakage or explosion of the batteries.

Relative Humidity Data Sheet (Hygrometer)

Study site name and location: ____________________ Month and Year: ________________

Time of data collection:

Local time: _______________________ Universal time: ____________________

Coordinates:

Altitude: ______________ Latitude: __________ Longitude: __________

Day of the Month	Relative Humidity (%)	Metadata
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		

Introduction to Clouds

GLOBE Aerosols and Clouds – Lesson 2

Materials / Preparation:

- Thermometer
- Photocopies of Cloud Identification Sheet for the students to look at *(optional)*
- Students' GLOBE notebooks

Lesson Plan:

Actual Temperature

1. Ask the different groups their estimates of the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group had the closest guess.

Introduction to Clouds

1. Explain: Often, water in the air gathers to form clouds.
2. Definition: A **cloud** is a visible mixture of very fine water particles, liquid or solid, kept in suspension in the troposphere and the stratosphere of the atmosphere.
3. How are clouds formed? Clouds are formed from small droplets of water coming from the condensation of water vapor at high altitude, where it is very cold.
4. Analogy: Clouds are the same thing as water vapor that leaves a pot or teapot of hot water. The only difference is that clouds are cold instead of hot.
5. Our goal in studying clouds is to make an observation of the sky each day around the same time. Then, we are going to send our data over the internet to scientists and GLOBE students all over the world.

Description of Clouds

1. Ask a student from each group to come to the blackboard and draw a cloud that he has seen. (If all the students draw approximately the same cloud, the teacher can draw one or two different cloud images himself.)
2. Ask those that drew images to verbally describe their clouds. Collect the words used (big, little, thick, thin, fluffy, like cotton, gray, black, white, dark, stormy, far, spread out, high, low, etc.) into three categories on the blackboard: Form, Color, and Altitude.
3. Explain that scientists use these three categories plus one more, the Ability of the Cloud to Produce Precipitation, to place clouds into 10 types.

The Different Types of Clouds

1. If you have them, give or show to the students the photocopies of pictures of clouds in order to facilitate the students' comprehension. If you don't have any, you can draw the clouds on the blackboard or walk around the room and show the students the images of the clouds in this guide.

2. There are ten types of clouds. The types (categories) of clouds are based on their form, their color, their altitude, and their potential for precipitation.
   a. Clouds can have three principal forms:
      Cumulus clouds are heaped and puffy
      Stratus clouds are layered
      Cirrus clouds are wispy
   b. Clouds are situated in three altitude ranges (specifically the altitude of the cloud base)

High Altitude Clouds (above 6000m) Designated by "Cirrus" or "Cirro-"

Cirrus – These clouds look like white delicate feathers. They are generally white wispy forms. They contain ice crystals.

Cirrocumulus – These clouds are thin white layers with a texture giving them the look of patches of cotton or ripples without shadows. They contain primarily ice crystals and perhaps some very cold water droplets.

Cirrostratus – These clouds are a thin, almost transparent, whitish layer made up of ice crystals. They may totally or partly cover the sky and can create a halo appearance around the sun.

Medium Altitude Clouds (2000 to 6000 m) Designated by "Alto-"

Altostratus – These clouds form a bluish or grayish veil that totally or partially covers the sky. The light of the sun can be seen through them but there is no halo effect.

Altocumulus – These clouds look like waves of the sea with white and gray coloring and shadows. They contain mostly water droplets and perhaps some ice crystals.

Low Altitude Clouds (below 2000 m) – No Prefix

The clouds that contain the word "nimbus" or "nimbo-" are the clouds from which precipitation is actually falling.

Stratus – These gray clouds are near the surface of the earth. Normally they cover the entire sky, but they can also form in pockets of the sky. They rarely produce rain.

Stratocumulus – These clouds are a gray or whitish color. The bases of these clouds tend to be more round than flat. They can be formed from old stratus clouds or from cumulus clouds that are spreading out. Their tops also tend to be mostly flat.

Nimbostratus – This is a very dark and gray-colored cloud layer that blots out the light of the sun. It is massive and has a continuous fall of precipitation.

Cumulus – These clouds have a flat base and a dense, mound-shaped top that resembles a large cauliflower. Where the sun hits these clouds they are a brilliant white. The base tends to be a darker gray. They generally do not produce precipitation.

Cumulonimbus – These are large, heavy, and dense clouds. They have a generally flat, dark surface with very tall and large tops like the shape of a massive mountain or anvil. These clouds are often associated with lightning, thunder and sometimes hail. They may also produce tornados.

Practice: Learning the Types of Clouds via the Cloud Hand Game

1. This game is a memorization aid that links actions to the different types of clouds.
2. Ask students to stand up. Give them gestures or movements that represent the different types of clouds. Ask the students to follow you.

    - **Stratus** – Hold your hands horizontally, spread apart
    - **Cumulus** – Hold your hands with your palms together
    - **Cirrus** – Hands held above your head.
    - **Altos** – Hands raised chest-level
    - **Nimbus** – Flutter your fingers to signal rain

3. Ask the students to do actions representing clouds with those root words combined, ex. cirrocumulus (palms together above their heads), nimbostratus (hands spread apart and held horizontally while fluttering fingers) and so on.
4. Work with the students on these actions as a game, asking them to show you different clouds faster and faster. Ask the students who err to sit down, and declare the last standing to be the winner.

Cloud Journal

1. Ask each student to check the sky each morning and each afternoon (at a set time) between now and the next lesson, and to write down the type of clouds they see. The teacher must take observations as well, as a form of quality control and to facilitate the discussion. Use the following format as a guide:

Date	Time	Type of Clouds Seen	Number or % seen, or other observations

Cloud Identification Sheet

High Altitude Clouds

Cirrus

Cirrocumulus

Cirrostratus

Medium Altitude Clouds

Altostratus

Altocumulus

Low Altitude Clouds

Stratus

Stratocumulus

Nimbostratus

Cumulus

Cumulonimbus

Contrails

Short-lived contrails

Persistent Non-spreading

Persistent Spreading

Review of Cloud Types

GLOBE Aerosols and Clouds – Lesson 3

Materials / Preparation:

- Clouds journals from the last lesson
- Thermometer
- Cloud Cover Data Collection Sheet
- 26 Cards for Cloud Game: On thirteen cards, write or paste the names of 10 types of clouds and 3 types of contrails. On thirteen other cards, glue an image of one type of cloud onto each one. (*Template cards are below.)* Make a set for each group in the class.

Lesson Plan:

Actual Temperature

1. Ask the different groups their estimates of the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group was the closest to reality.

Examination of Cloud Journals

1. Make a daily summary of clouds in a chart on the board that the students have seen. During the discussion, the teacher should compare their answers to his or her own observations. In this manner, the teacher can guide the students to make accurate observations.

Review of the Types of Clouds: Cloud Memory Card Game *(for 2-6 students)*

1. Preparation of one set of game cards for each group in the class (by the teacher or the students): On thirteen cards, write or paste the names of 10 types of clouds and 3 types of contrails. On thirteen other cards, glue an image of one type of cloud onto each one. (*Template cards are below.)*
2. Mix the cards and lay them face down one by one in rows on a table around which the students are gathered.
3. The first player turns over 2 cards, trying to find a match of a picture with its correct word. If he doesn't find a match on his first try, you turn the cards back face-down in the exact places that they came from and the next player tries to find a match by turning over another two cards. When someone finds a pair, he keeps the pair and gets to have and extra turn, and so on until he doesn't find a match at which point turn passes to the next player.
4. Make sure that the student turning over the cards shows the other students in the group what cards have been turned over.
5. Explain to the students that they need to remember what is on the cards that have been revealed and where they are located so they can correctly match the names and the images when it is their turn. Explain that this game is not one of chance, but of skill in memorization.
6. The winner is the player with the most cards when all the pairs have been collected.

Setting up Daily Observations of the Sky

1. While the students do not yet know every aspect of the data collection sheet for cloud cover, they can still start making daily observations of the sky.
2. Set up a rotation system whereby a different group goes outside at the same time each day to make observations of the sky and fill in as much of the data sheet as they can, leaving blank the parts that they have net yet been trained on. Over the course of the next several lessons the students will learn how to fill in the rest of the data collection sheet until they are capable of making a complete observation.
3. The data collection sheet can be found at the end of this lesson.

More Review

1. If you have the time, play the cloud types hand movement game from last week's lesson to reinforce the categories of clouds in the students' minds.

Cloud Cover Data Sheet

School Name: ____________________ Study Site: ______________________

Names of the Observers: ________________________________

Date: _______________

Local time of observation: _____________ Universal time of observation: __________

Types of Clouds (check all types that are observed)

Cirrus		Altocumulus		Stratus	
Cirrocumulus		Cumulus		Stratocumulus	
Cirrostratus		Nimbostratus		Cumulonimbus	
Altostratus					

Cloud Cover Amount (check 1)

No clouds (0%)		Scattered Clouds (25%-50%)		Obscured sky	
Clear (0%-10%)		Broken clouds (50%-90%)			
Isolated clouds (10%-25%)		Covered sky (>90%)			

Type of cloud contrails (Number of each type observed)

Short-lived contrails	
Persistent non-spreading contrails	
Persistent spreading contrails	

Amount of contrail coverage (check 1)

None		10-25%		>50%	
0-10%		25-50%		Obscured sky	

State of the Sky (Check one per column)

Color	
Deep Blue	
Blue	
Bright blue	
Pale blue	
Milky	

Clarity of the sky	
Exceptionally clear	
Lightly hazy	
Very hazy	
Extremely hazy	

Sky obscured by	
Fog	
Smoke	
Haze	
Volcanic Ash	
Dust	
Sand	
Ocean spray	
Heavy rain	
Snowstorm	
Blizzard	

Current Air Temperature : _________ºC

Relative humidity (if known) : _________%

Commentaries: Describe any conditions that could affect your measurements such as urban pollution, smoke from brush fires, sand storms, dust storms, dust arising from agricultural activities etc:

____

____

Words for the Cloud Game (Memory)

CIRRUS

CIRROCUMULUS

CIRROSTRATUS

ALTOCUMULUS

ALTOSTRATUS

CUMULUS

STRATUS

STRATOCUMULUS

CUMULONIMBUS

NIMBOSTRATUS

SHORT-LIVED CONTRAILS

PERSISTENT NON-SPREADING CONTRAILS

PERSISTENT SPREADING CONTRAILS

CIRRUS

CIRROCUMULUS

CIRROSTRATUS

ALTOCUMULUS

ALTOSTRATUS

CUMULUS

STRATUS

STRATOCUMULUS

CUMULONIMBUS

NIMBOSTRATUS

SHORT-LIVED CONTRAILS

PERSISTENT NON-SPREADING CONTRAILS

PERSISTENT SPREADING CONTRAILS

Pictures for the Cloud Game (Memory)

Clouds










Contrails

(Use now as an introduction for the following contrails lesson)



Cloud Cover

GLOBE Aerosols and Clouds – Lesson 4

Materials / Preparation:

- A4 paper or double-sheets from the students' notebooks
- Old newspaper *(to make clouds)* cut to the size of A4
- Ruler to divide the A4 sized pieces of newspaper into 10 equal parts
- Scissors or a razor blade
- Glue or a roll of scotch tape
- Thermometer
- Students' GLOBE notebooks

Lesson Plan:

Actual Temperature

1. Ask the different groups their estimates of the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group was the closest to reality.

Cloud Cover

1. Definition: **<u>Cloud Cover</u>** is the percentage of the sky covered by clouds.
2. Review the concept of percentage with the students: If something is divided into one hundred parts, each of the parts represents $1/100^{th}$ of the whole, or 1% of the whole. For example, if a box of sugar is divided into 100 sugar cubes, one of those sugar cubes represents 1% of the total box; 10 of those sugar cubes represent $10/100^{th}$ or 10% of the total box.
3. Explain that during the estimation of cloud cover, the sky is divided into 100 parts and the observer has to estimate how many of those 100 parts, or what percentage of the sky is covered by clouds.
4. Explain that there are fixed terms which describe different percentages of cloud cover. These terms are as follows:
   a. 0% - No clouds or Cloudless sky
   b. <10% - Clear sky
   c. 10-25% - Isolated clouds
   d. 25-50% - Scattered clouds
   e. 50-90% - Broken clouds
   f. >90% - Overcast
   g. Obscured sky – meaning you can't see the sky well because of fog, haze, smoke, dust, sand, rain, volcanic ash, etc.
5. Good cloud cover estimates require practice because normally people make too high of estimates at the beginning.

Exercise: Estimation of Cloud Cover

1. Cut the sheets of newspaper so that they are the same size as a sheet of A4 paper.
2. Then, cut each sheet of newspaper in ten equal parts (each part is then 10% of the total).
3. Divide the room into ten groups, and then give 10 cut-out sheets and a sheet of A4 to each group.
4. Assign each group a multiple of 10 from 10% up to 100%.
5. Each group then takes a number of their 10 pieces equal to their percentage. For example, the group that will represent 30% will use 3 of their 10 pieces.
6. The students then tear their sheets of newspaper into irregular-shaped pieces representing the clouds.
7. The students glue or tape these torn pieces on the white A4 sheets (representing the sky) in the shape of clouds. Make sure that the students glue all of the pieces of the newspaper to the sheet and that there are no scraps left over.
8. The scraps can be grouped to represent clouds, but they must not overlap!
9. On the back of the sheet, the students should write their percentage.
10. Then have each group go to the front of the room to present their representation sheet to the class.
11. By posting the 10 representations on the board or collecting them in a folder to take outside, the students will have a cloud cover guide.
12. It would be helpful to look at these percentage representations each time the students go outside to do their cloud cover observations, or at least until they can make accurate observations of the different percentages of cloud cover in the sky by themselves.

Exercise/Additional Game:

1. Using the remainder of the 10 sheets and a new sheet of A4, have the students construct cloud cover sheets a second time, but this time each group chooses a percentage itself without telling the others.
2. Once they have finished their constructions, have each group come in turn to the front of the class to show the others their work.
3. Each group at their desks should write down their estimate of the coverage for on a scrap of paper.
4. Once all of the groups have finished, the teacher can reveal the answers and award points to each group for each correct answer in order to name a winner.

Application: Estimate of Cloud Cover Outside

1. Divide the students into groups of 5 and go outside as a class to a location that provides a non-obstructed view of the sky.
2. Four of the students in each group should then stand up straight back-to-back with each one looking in a different cardinal direction.
3. Then, they should raise their arms to form an angle of 90 degrees in front of them. If they have done this correctly, the length of their arms should be touching those of their neighbors.

4. Each of the four (with the A4 sheets in front of them if they need assistance) should now make an estimate of the cloud cover in their quarter of the sky (between their outstretched arms all the way up to a point right above their heads.
5. The fifth student is the recorder and should write down the estimate of each observer. Then, by averaging the four numbers, the recorder will have a percentage for the entire sky.
6. Do this exercise several times, rotating each group each time so that each student can practice estimating for different views of sky.
7. Check the average percentage of each group with those of the others to ensure that all the groups are coming up with about the same number. If there is a group that consistently produces data that is far from the other groups', have them practice more on the A4 sheets before continuing further.
8. Remind the students that they will now need to add this estimation to their data collection each day that they go outside to make GLOBE observations.

Note: As students become more expert in this measurement, they will begin to realize that clouds are three dimensional and have thickness. As one looks toward the horizon, the sky can appear to be more cloud covered than it really is because the spaces between clouds are hidden from view. This effect is more pronounced for low clouds than for middle and high clouds. It is also more of an issue for cumulus clouds than for stratus clouds.

If when looking directly overhead students see a pattern of cloud cover with individual puffs or long rolls of cloud separated by clear areas, and the general appearance of the clouds is similar looking toward the horizon, it is reasonable to infer that there are spaces between these clouds as well and the cloud cover is not 100% toward the horizon.

Contrails and a Review

GLOBE Aerosols and Clouds – Lesson 5

Materials / Preparations:

- Thermometer
- Cloud Cover Data Sheet
- Cloud Identification Sheet (*at the end of the lesson: Introduction to clouds*)
- Chalk, meter stick
- Wadded-up piece of paper
- Students' GLOBE notebooks

Lesson Plan:

Estimate of the Actual Temperature

1. Ask the different groups their estimates of the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group is the closest to reality.

Contrails

1. In addition to clouds, we are going to also measure **<u>contrails</u>**, the lines of vapor created by the jet engines of airplanes.
2. There are three sorts of contrails:

<u>Short-lived contrails</u> – These contrails disappear rapidly and form short line segments in the sky that fade out as the distance away from the airplane that created them increases. (sign of lightly humid air high up in the atmosphere)

<u>Persistent Non-Spreading</u> – These contrails exist long after the airplane that made them has left the area. They form long straight lines of approximately constant width across the sky. These contrails are not larger than your index finger at arm's length (sign that the air is humid above)

Persistent Spreading–These contrails also exist long after the airplane that made them has left the area. They form long streaks that grow wider and fuzzier as the distance from the plane that created them increases. These contrails are larger than your index finger at arm's length (sign of very humid air at high altitudes)

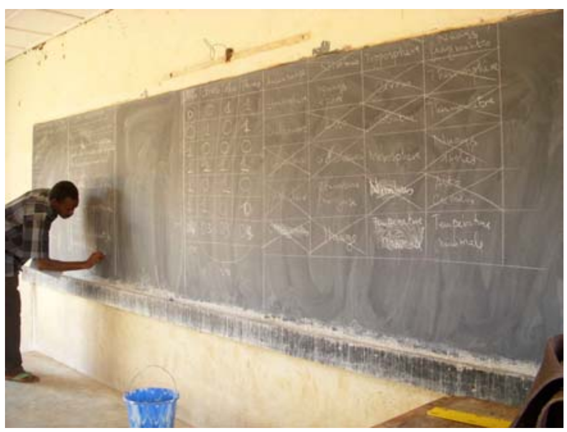
3. When you are estimating the percentage of the sky covered by contrails, know that <u>in general one contrail covers less than 1% of the sky</u>.
4. If you have not already done so, put in place a system whereby a group of students observes the sky and records their findings on the Cloud Cover Data Sheet. The students can be charged with making observations during the weekend as well.

Game: Vocabulary Review on the Blackboard

1. Ask the students to put away all their papers, close their notebooks, and sit in teams.
2. Draw a table on the blackboard and fill the squares with various vocabulary words from our study of aerosols:

No Clouds	Nimbus	Troposphere	Broken Clouds
Stratosphere	Short-term contrails	Scattered clouds	Cirrus
Covered Sky	Alto	Stratus	Hygrometer
Cumulus	Obscured Sky	Thermosphere	Isolated Clouds
Persistent spreading	Clear sky	Non-persistent spreading	Cloud Cover
Humidity	Overcast	Relative Humidity	Cloud

3. Give a student in the first group a piece of waded up paper and ask him to throw it at the blackboard. He must now define the word in the square that he hit. If he correctly defines the word in the square where the paper hits, mark a point for his team and erase the word from the blackboard. Then, a student from the next team throws the paper and tries to give the definition. If he hits a blank square, he passes the paper to the next group, until all the squares are blank and a winner is declared based on the points earned.



Formation and Importance of Clouds

GLOBE Aerosols and Clouds – Lesson 7

Materials / Preparations:

- Diagram of Water Cycle *(below)*
- Students' GLOBE notebooks

Lesson Plan:

Actual Temperature

1. Ask the different groups their estimates of the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group's guess was the closet to the actual temperature.

Explaining the Formation of Clouds via a Description of the Water Cycle

1. For this lesson, use the attached water cycle description with or without modifications (or any other water cycle description that you have) according to the level of the students.
    a. Regardless of which water cycle description you use, be sure to emphasize two aspects: as we are studying clouds, focus on the creation of clouds through evaporation and the role that trees play in the creation of localized rain and cloud formation, as it is part of the cycle that is often overlooked.
2. Explain to the students that together we are going to create the Water Cycle on the blackboard and later they will copy it into their notebooks.
3. Explain that the cycle is important because it demonstrates how all of the water in the world is connected, from the pond outside during the rainy season to the Pacific Ocean near the United States. Explain that clouds play an integral role in this cycle.
4. Ask the students to share some of the ideas they came up with during their homework as to how the water cycles through our environment. Encourage the students through complimenting their answers.
5. Then, explain that we are going to now see the exact path that water takes through the whole water cycle.
6. Draw the water cycle on the blackboard, piece by piece, while at the same time following this series of questions:
    a. Draw an ocean (and/or a lake). Ask what will happen when the sun hits the surface of the ocean or any body of water. (Response: **evaporation** of some of the water.)
    b. Draw the water vapor leaving the ocean and ask students what will happen when the water vapor reaches a high altitude. (Response: the formation of clouds.)
    c. Draw some clouds and explain that some of the clouds will move from over the ocean (or lake) to the land, pushed by the wind. Ask what will happen to the water vapor contained in the clouds. (Response: it forms **precipitation** – rain, snow, etc.)
    d. What happens to the precipitation when it falls?

i. 31% of precipitation runs over the surface of the earth and into rivers, streams, lakes, reservoirs, and ponds. This is called **runoff**. Some of this water will run all the way back to an ocean to restart the cycle!

ii. Some of it gets stored in ice caps: Precipitation falls on top of huge pieces of ice at the Poles, called **ice caps**, and is stored there as ice.

Note: Ice caps are huge pieces of ice by the North and South Pole that are at risk of melting because of Climate Change, also called Global Warming. If the polar ice caps melt, the level of the oceans will raise many meters and create problems the world over.

iii. Much of this precipitation is evaporated back into the air to form new clouds.

iv. Tell the students that some of this precipitation soaks into the soil and enters into another very important part of the water cycle:
   - Some of this precipitation soaks into the soil. This is called **infiltration**.
   - About 3% of water from rains soaks into the soil and passes to a great depth to become **groundwater**, held in large underground reservoirs.

v. Water is taken up from the soil and from underground reservoirs by plants and trees respectively.
   - This water is then evaporated from the plant's leaves, creating local water vapor. Evaporation of water from the leaves of plants is called **transpiration**.
   - If there are a lot of plants in a given area, especially a lot of trees, the evaporation is enough to produce local clouds and then rainfall.

e. Review: So, the water from precipitation goes to five places: runoff, ice caps, evaporation, transpiration, and infiltration.

   i. As it is often hard to tell the difference between the effects of evaporation and transpiration (what water vapor comes from what process), the two processes are often combined into one word, **evapotranspiration**.

   ii. About 66% of rainfall returns to the atmosphere through evapotranspiration from the surface of the earth.
      - Most of the rain in forests comes in this way. So, if people cut down all the trees in a region, they can lose much of the rain in that region at the same time.

7. At the end of the explanation, tell students to copy the water cycle into their notebooks. You could also ask them to explain their drawing to a partner once they are finished and waiting for the others.

Clouds' Role in Forecasting (Predicting) the Weather

1. Meteorologists and other people who have lived in a region for a long time use clouds to forecast (predict) the weather and note its arrival, its direction of movement, its size, its form, and its position in the sky.
2. With your regular observations for GLOBE, you too will be capable of forecasting the weather!
3. Clouds can tell us about dry periods, rain, storms, snow, tornadoes, etc.

Clouds and the Climate

1. Clouds and the climate are both based on each other. For example, in the south of Benin, near the ocean, there is a lot of evaporation from trees and the ocean to create more clouds and more rain; thus creating a tropical climate. On the contrary, Niger is far from the ocean and only a little of the vapor from the ocean can make it here. Also, there are not many trees to start with. So, this situation produces less water vapor, resulting in fewer trees and less rain in general.

Importance of Clouds

1. Clouds serve as a layer of protective insulation for the Earth. Clouds reflect a lot of solar rays from the sun back out into space. This reduces the amount of sunlight reaching and heating the surface of the Earth. This has a cooling effect and it reduces the temperature of the Earth by 20˚C. In fact, human life on this earth would be impossible without clouds because the temperatures would be too high for us to survive.
2. Locally, clouds can also act as a blanket, reflecting heat back towards the Earth as it tries to leave. So, sometimes clouds keep the Earth warmer than normal too.

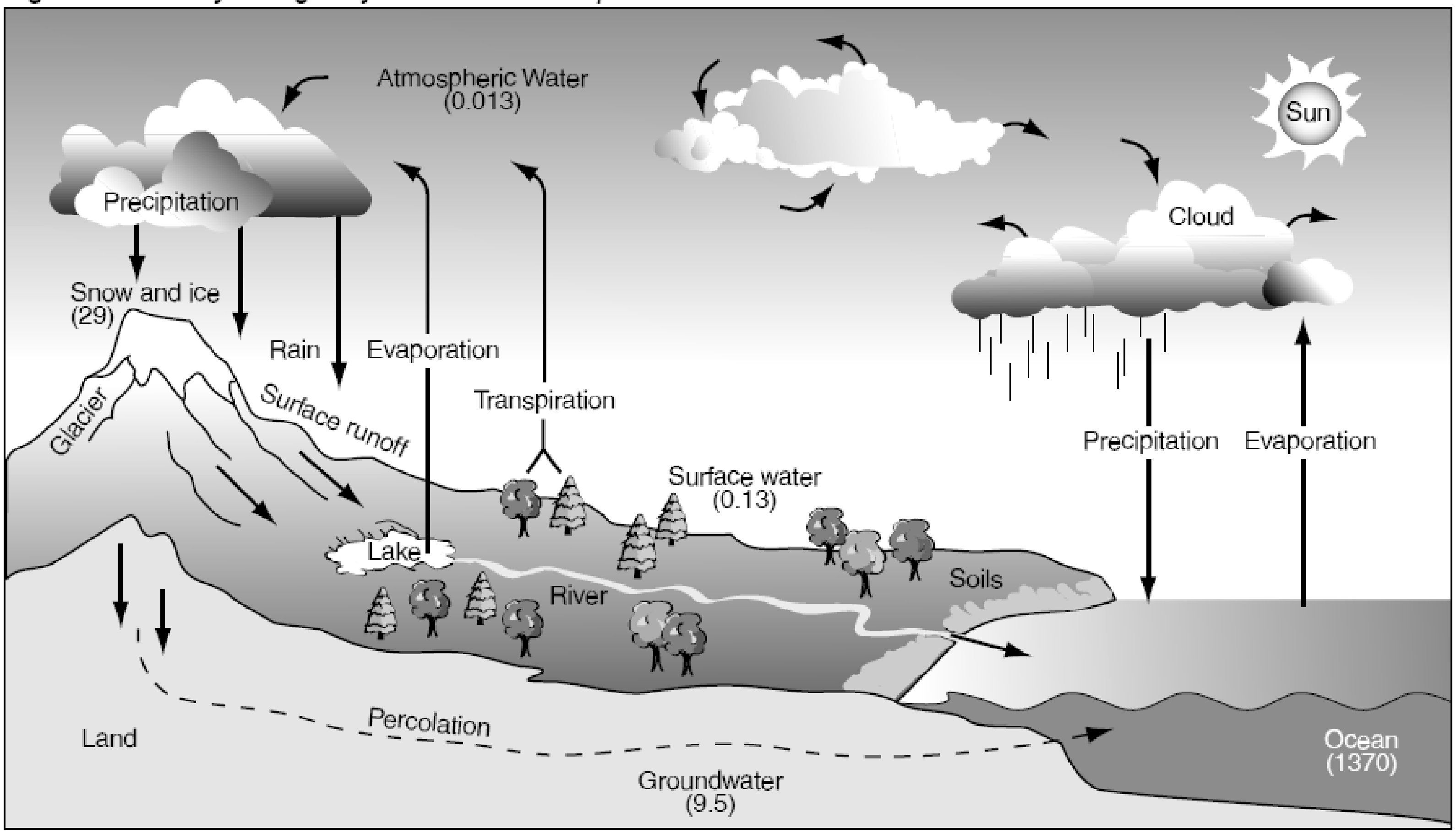
Exercise in Groups or Individual:

1. Ask the students to draw another cycle of your choice that is based on water. (For example: the life of a plant, the life of an animal, seasons, the level of a river or lake, the flowering of a tree, bird migration, etc.)
2. Select a few students to share their cycles with the class.

Hydrologic Cycle

GLOBE Atmosphere – Water Cycle

Figure HY-I-1: Hydrologic Cycle - Numbers in parentheses are the reservoirs of available water in 10^3 Km^3.



After Mackenzie and Mackenzie 1995, and Graedel and Crutzen, 1993

Introduction to the Rain Gauge and Reading a Graduated Cylinder

GLOBE Rain Gauge – Lesson 1

Materials / Preparations:

- Thermometer
- Rain Gauge *(commercially of locally fabricated)*
- Graduated cylinder
- Students' GLOBE notebooks

Lesson Plan:

Game: Estimating the Actual Temperature

1. Ask groups their estimate of the actual temperature and write them on the blackboard. Ask several students to read the alcohol thermometer and see which group had the best estimate.
2. Explain the importance of knowing how to make good estimates.
3. If you haven't already done so during another lesson, have a contest for making other estimates. For example, each group estimates the size of various objects in the room. Then measure the objects with a ruler and verify which group was the closest.

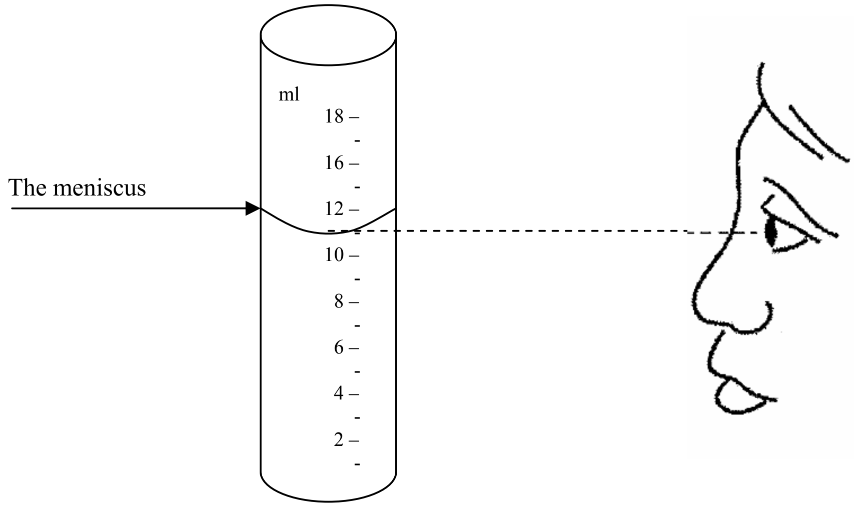
Introduction to the Rain Gauge

1. Definition: A **rain gauge** is a tube topped with a funnel that empties into a graduated cylinder. It is used to measure the quantity of precipitation that falls during a storm. Sometimes, the graduated cylinder becomes so full of rain that it fills up and the extra collects in an overflow tube.
2. A rain gauge is attached to a low and perfectly vertical post so that the wind above doesn't affect the measurements and so that water doesn't splash up off the ground into the gauge and skew the measurements.

Introduction to a Graduated Cylinder

1. Definition: A **graduated cylinder** is a clear tube with a scale printed on its side. It is used to measure the volume of a liquid usually in milliliters.
2. How to read a graduated cylinder:
    a. Water in any container climbs the edges of the container. This action creates a rounded and concave surface, called a **meniscus**. (For advanced classes: you can explain that the liquid climbs the edges because of adhesion, a mechanism by which polar molecules of two materials attract each other. This is called **capillary action**.)
    b. So, to measure the quantity of a liquid, put your eye at the same level as the meniscus. Then, line up the bottom of the meniscus with the scale and record the volume indicated.

Image:



Review Game: Reading a Graduated Cylinder

1. Draw 4 or 5 graduated cylinders on the blackboard and draw a scale of your choice for each one.
2. Draw a meniscus in each graduated cylinder to show the level of water in each one.
3. Ask each group to work as a team and read the volume of each graduated cylinder. Have them write down the answers as a group.
4. Verify the measurements of each group and give points to each team who answered correctly.
5. Explain the correct answer to those groups who do not answer correctly.
6. Take out a graduated cylinder if you have one. Put a quantity of water into the graduated cylinder and ask each team to come and read the graduated cylinder and write down their response. Make sure that you are using this opportunity to coach them on their reading technique, such as placing their eye at the same level as the meniscus.
7. Give points to each team that read the correct volume.
8. Repeat several times.
9. Finally, give some chalk to the team with the most points and they can now lead the game; drawing the meniscus on the graduated cylinders on the blackboard and having the other teams find their volumes.

How to Use a Rain Gauge

GLOBE Rain Gauge – Lesson 2

Materials / Preparation:

- Thermometer
- Rain Gauge (directions for construction are below if needed)
- Graduated Cylinder
- Precipitation Data Sheet *(below)*

Lesson Plan:

Game: Estimating the Actual Temperature

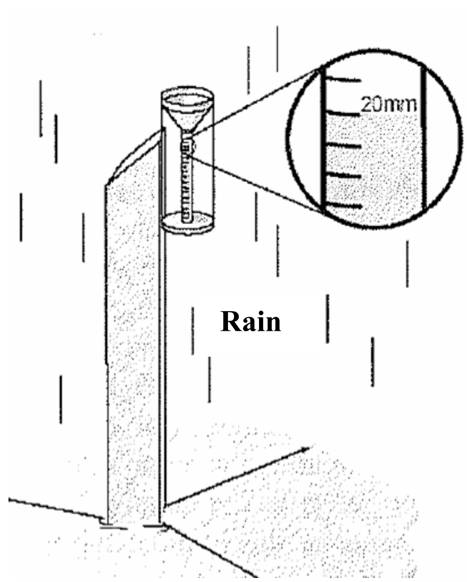
1. Ask the different groups to estimates the actual temperature and write their estimates on the blackboard. Ask several students to read the alcohol or mercury thermometer and see which group made the best estimate.

Steps for Using a Rain Gauge

(Work with the students on this process so they will be able to take data on their own in the future.)

1. Visit the rain gauge every day to make sure it is clean and does not contain any water.
2. After a rain or other precipitation, take the graduated cylinder out of the rain gauge and place it on a flat surface.
3. Read the level of water in your rain gauge; make sure your eyes are level with the water contained in the graduated cylinder. On the Precipitation Data Sheet (below), record the number of the scale that is aligned with the bottom of the meniscus.

   *Note: The scale of the rain gauge is in **mm** of rain, not **ml** of rain – the conversion is already done and worked into the scale on the side of the cylinder by the company that made it. So, you should record the number directly as mm of rain.*



4. Record the rainfall amount to the nearest one-tenth of a millimeter.
    - If there is no water in the rain gauge report 0.0 mm.
    - If there is less than 0.5 mm, record “T” for trace.
    - If you spill any water before measuring the amount of rain, record “M” for missing as the amount. (If you have only spilled a little, record the amount not spilled as metadata for that day.)
5. Pour the water into the pH sampling jar and cover it for the pH measurement (if you have the necessary equipment for the pH protocol)
6. If there is water in the overflow tube:
    a. Remove the graduated cylinder from the overflow tube.
    b. Dump out the water that you just measured from the graduated cylinder.
    c. Pour some water from the overflow reservoir into the graduated cylinder and measure its volume.
    d. Repeat steps **b** and **c** until the overflow tube is empty.
    e. Add up your measurements, and record the total on your data sheet.
7. If it has been some time since you have been to the rain gauge, note the number of days during which the rain accumulated (the number of days passed since the last time the rain gauge was checked and emptied)
8. Dry the rain gauge and put it back in place.

Upkeep of the Rain Gauge

1. Even if it hasn’t rained you must check your rain gauge each day to be sure that there is not any debris inside.
2. Certain birds seem to like to sit on the edge of the rain gauge and leave their droppings behind. So, around once a month, the rain gauge should be conscientiously cleaned with a brush. Never use soap or a detergent to clean the rain gauge because the residues can contaminate the pH of precipitation. If you are taking pH measurements, consider rinsing the rain gauge with distilled water after cleaning it.
3. In the brush, children carrying slingshots and football players threaten to break plastic rain gauges. So, we advise you to have a tinsmith make a metal sleeve to protect this type of rain gauge. Verify that the sleeve can be mounted on the post and that its edge is well below that of the rain gauge so that it does not create a draft that will affect the data.

Visit the Rain Gauge Site

1. Show the students how the rain gauge is fixed in place.
2. Show them how to lift the rain gauge off the post to take data.
3. Show them how to clean the rain gauge.
4. With the students, practice lifting it off and cleaning it.

How to Make a Rain Gauge (if necessary)

If you have acquired a graduated cylinder but you don't have a rain gauge, you can make a rain gauge yourself following these instructions. See also "Installation and Fabrication of a Rain Gauge".

Find a rather deep, straight-walled, and circular container with a thin lip. Our suggestion is to use two big tomato past cans attached together one on top of the other with the bottom of the top can removed (have a tinsmith build this as well). Attach it to a post or on a flat object raised 0.5m off the ground with a rubber cord or another method that allows for easy removal, does not put a hole in the container itself, and does not block the container's opening.

Now, to calculate the depth of the rain collected, you can do the following calculation:

$$\text{Depth of precipitation} = \frac{\text{Volume of water in ml x 10}}{\text{Area of the interior of the container in cm}^2}$$

Here is how you find the area of a circle: π x Rayon^2

$$\text{And the radius} = \frac{\text{Diameter of the circle}}{2}$$

Precipitation Data Sheet

Study site name and location: ______________________ Month and Year: ____________

Time of Data Collection:

Local time: _______________________ Universal time: ____________________

Coordinates:

Altitude: _____________ Latitude: _________ Longitude: _________

Day of the Month	Number of days since the last visit to the rain gauge	Millimeters of precipitation	pH (If you are taking it)	Metadata
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				

Taking the pH of Precipitation Using pH Paper and Table Salt

GLOBE Rain Gauge – Lesson 3

<u>*Note*</u>*: If you have the means, this procedure should be done each time that precipitation is taken from the rain gauge.*

Materials / Preparation:

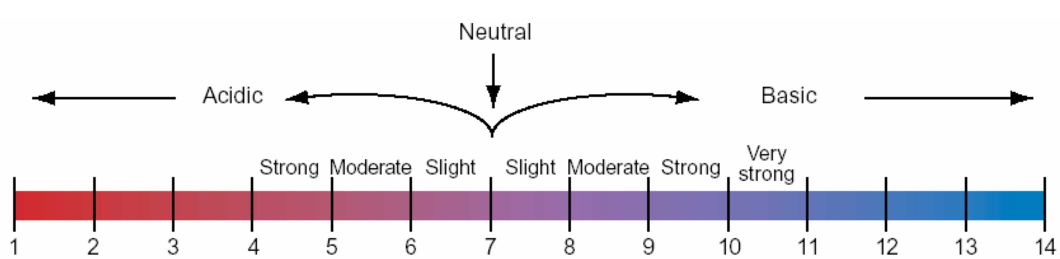
- Table salt
- Salt card (*see image below*)
- Spoon
- pH paper or pH meter
- Tweezers
- A small clean cup or jar
- At least 30 ml of precipitation
- Distilled water*
- Students' GLOBE notebooks

  <u>Note</u>: *In Niger, the round bottles labeled distilled water from Côte d'Ivoire are not distilled water and are less pure than the tap water here. Also, the battery shops in Niamey claiming to have distilled water actually only have filtered water from the Caterpillar machine shop. The only true distilled water that we have identified in Niger is the locally made distilled water from CNES (20.72.39.23) in the square plastic bottles. The Total gas stations around town usually carry CNES distilled water but the OiLibya stations do not.*

Lesson Plan:

Explaining pH to the Students

1. Explain that all liquids are acidic, basic, or neutral. Pure water is neutral.
2. Give the students the following definition of pH: **<u>pH</u>** is a measurement that allows us to say whether a liquid is acidic, basic, or neutral.
3. The pH Scale ranges from 1 to 14 on a number line. Therefore, 7 (the pH of pure water) is in the center and is considered neutral. pH readings between 1 and 7 are called **<u>acidic</u>** with 1 being the strongest acid. pH concentrations between 7 and 14 are **<u>basic</u>** with 14 being the strongest base.
4. Draw the following number line on the board to help the students understand the idea of the pH scale:



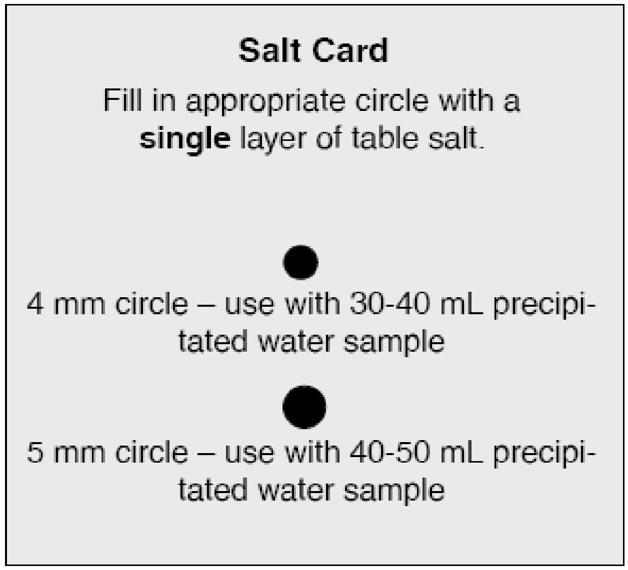
5. Acids and bases have many varied and different uses. For example, many bases are used as solvents or in soaps for cleaning. Acids in our stomachs break up the food that we eat so we can absorb all of the nutrients out of the food and into our bodies.
6. If you have an upset stomach or heartburn, a glass of milk can help calm it. This is because milk is a base and it **neutralizes** (cancels out) the acids in your stomach to stop the burning.
7. So, it is important for us to know if a liquid is acidic or basic because this can help us know how to use it. We measure pH using pH paper or a pH meter.
    a. **pH paper** is chemically treated paper that undergoes a chemical reaction when it comes into contact with an acid or base. This reaction changes the color of the paper. By matching up the color change of the paper with a scale, we are able to know the pH of a liquid.
    b. A **pH meter** is a piece of electronic equipment that has two probes. When these two probes are placed into a liquid, they are able to measure the pH using electricity and then display the pH on a screen so we can read it.

Explaining Why Measuring the pH is Important

1. Water circulates on the inside of every living thing. So, chemicals in the rain can affect the lives and environments of these living things as they move around with the water.
2. These chemicals come from gasses in the air that dissolve into raindrops. Often, these chemicals come from human activities such as burning trash, driving cars, etc.
3. Normally, precipitation is slightly acidic. But the addition of chemicals lowers the pH of the precipitation. **Acid rain** is precipitation that has a pH lower than 5.6.
4. Acid rain is very bad for the environment and living things:
    a. It weakens plants and makes them more susceptible to dying
    b. It eliminates elements from the soil that are essential to plant growth
    c. It releases elements into the soil that are poisonous to plants and to the animals that eat those plants
    d. It speeds up the rate of metal corrosion (rusting) and the destruction of buildings and monuments (natural and man made)
    e. It kills many aquatic animals such as fish and amphibians.
5. If one wants to stop acid rain, one needs to know its sources, the changes in its concentration, and its effects on the environment. GLOBE pH measurements will help scientists and governments to track and fight against this problem.

Taking Measurements

1. From the collected rainwater (precipitation), pour 50 ml (or less if you do not have 50 ml) of the liquid into a small cup or jar that has been cleaned and rinsed with distilled water three times. You must have at least 30 ml of precipitation in order to measure pH.
2. Do not touch the water or the salt with your hands as the acidity of your hands will contaminate the sample.
3. With a new plastic bag placed over your fingers, or with tweezers, place a pinch of table salt on the appropriate circle of the Salt Card below. If the sample of rain is between 40 and 50 ml, use the circle that is 5 mm in diameter. If the sample is within 30 and 40 ml of rain, use the 4 mm diameter circle.



Note: The salt helps the pH paper or the pH meter accurately measure the pH of the rainwater.

4. Fill the appropriate circle with a single layer of salt. Take off all of the extra salt that you did not use to fill in the circle.
5. Add the salt covering the circle on the Salt Card to the rainwater in the cup.
6. Completely mix the contents of the cup with a clean spoon that has been rinsed with distilled water three times.
7. Tear off a piece of pH paper that is about 2 cm long. Be careful not to touch the pH paper with your hands.
8. Hold the pH paper with a pair of tweezers or another acceptable method and dip it into the mixture for two or three seconds (or as indicated by the instructions that came with the brand of pH paper you are using).
9. Take the pH paper back out of the liquid and compare its color to the color scale that came with the pH paper (This is often printed on the pH paper container itself).
10. Record the pH of the precipitation on the Data Sheet for pH.
11. If you still have unused rainwater that has not been mixed with salt, rinse the cup and spoon three times with distilled water and repeat steps 1-11 two more times for a total of three measurements. On the contrary, if you do not have enough liquid to do two more tests, repeat steps 7-10 with the sample that you have already mixed.
12. Calculate the average of the three pH measurements and record it on the data sheet.
13. Verify that the pH of each of the three measurements you made is within one pH unit (number) of the average. If this is not the case, redo the procedure.
14. Rinse the cup and the spoon three times with distilled water and put them away for the next measurement.

Data Collection Sheet for Precipitation pH

Name of School and Study Site: ______________________

Date: _____________________

Time of data collection:

Local Time: __________ Universal Time: __________

Observers' Names: ____

Measurement Method (check one): ❑ pH paper ❑ pH Meter

Trial Number	Observer's Name	Measured pH	Average pH
1			__________
2			
3			

Observations and Metadata: ____

____